Forest Research

Wirral i-Tree Eco Technical Report

The Research Agency of the Forestry Commission

Forest Research

Forest Research is the leading UK organisation engaged in forestry and tree related research. The Agency aims to support and enhance forestry and its role in sustainable development by providing innovative, high quality scientific research, technical support and consultancy services.

i-Tree

i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools, including i-Tree Eco. The Forest Service, Davey Tree Expert Company, National Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, and Casey Trees have entered into a cooperative partnership to further develop, disseminate and provide technical support for the suite.

A project for Wirral Borough Council.

WIRRAL

Citation

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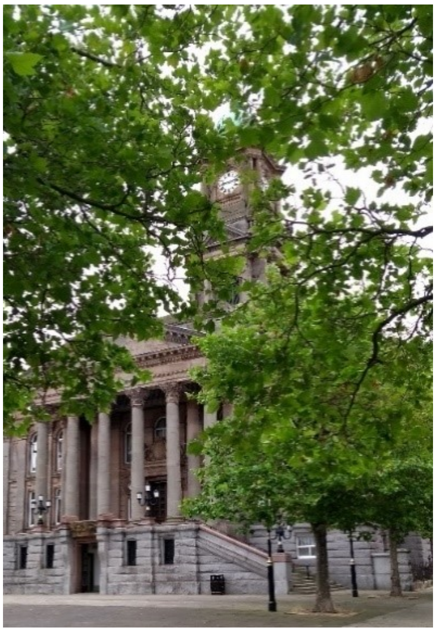
Copies of this report and of its summary can be downloaded from:

https://www.forestresearch.gov.uk/research/i-tree-eco/i-tree-eco-projects/i-tree-eco-wirral/

Images

Taken in 2022 on behalf of the project by John Morris Arboricultural Consultancy, Wirral Borough Council, and Forest Research.


Contents

Key Definitions

Urban forest: 'all the trees in the urban realm – in public and private spaces, along linear routes and waterways, and in amenity areas. It contributes to green infrastructure and the wider urban ecosystem' (Doick et al., 2016).

i-Tree Eco: a software application which quantifies the structure and environmental effects of urban trees and calculates their value to society. It was developed as the urban forest effects (UFORE) model in the 1990's to assess impacts of trees on air quality and has since become the most complete tool available for analysing the urban forest. Eco is widely used to discover, manage, make decisions on and develop strategies concerning trees in urban landscapes – www.itreetools.org.

Ecosystem services: benefits provided to people by the natural environment – such as clean air, food, places for exercise, and connection to our surroundings.

Social and cultural values: the non-material benefits people obtain from ecosystems, or the non-material values that people place on them. Examples are recreation and physical and mental health, opportunities for tourism, aesthetic appreciation, spiritual experience, and sense of place.

Executive Summary

Urban trees provide vital benefits that contribute to living comfortably in built-up areas. These benefits, called ecosystem services, include improving local air quality, reducing flooding, providing habitat for wildlife, and creating pleasant places.

As ecosystem services are often not marketable, they are generally undervalued, and inventories limited. This can lead to poor decision making about the management and maintenance of the components of the natural environment that provide them.

To gain knowledge about the structure and composition of Wirral's tree population, a sample-based survey was undertaken in 2022. 246 plots were surveyed across urban and rural areas and the data was processed using i-Tree Eco.

i-Tree Eco is one of a suite of tools developed by the USDA Forest Service and partners. i-Tree Eco combines a sampling and surveying methodology with a statistical model to extrapolate survey data to a whole study area, and a numerical model of tree biological function and ecosystem service provision.

This report provides a detailed description of the structure, composition, and condition of Wirral's trees, and demonstrates the importance of the tree population to local people. It captures a moment in time and does not account for how the tree population will change in the future.

It is estimated that there are more than **1 million trees** in Wirral. Wirral's trees provide annual benefits worth **£7.7 million per year**. This annual value includes just three ecosystem services: avoided surface runoff, carbon sequestration, and air pollution removal, and is an underestimate of the total annual value. Many ecosystem services cannot yet be quantified or valued. To replace the public amenity the trees provide would cost **£22.6 billion**.

This is the first i-Tree Eco project to incorporate measurements of **social and cultural values**. Residents were invited to take part in a survey about their attitudes to trees in their local area. Local people value trees because of their importance for **wildlife**, their contribution to **mental and physical wellbeing** and **air pollution removal**, and because they provide a **connection to nature**. There are fewer trees and lower provision of benefits in areas with higher deprivation, and people living in these areas would like to see **more trees planted in their neighbourhood**.

This project was funded by Wirral Borough Council and carried out by Forest Research. Fieldwork was undertaken by John Morris Arboricultural Consultants, and by Wirral Borough Council. Our thanks go to Wirral's residents and landowners for granting access to their property to undertake the essential survey work.

Headline Facts and Figures

Structure and composition of Wirral's urban forest in 2022		
Estimated total number of trees	1,022,000	Pg. 51
Estimated average tree density (trees per ha)	65	Pg. 51
Estimate of total tree canopy cover (%)	13.8%	Pg. 48
Number of tree species surveyed	74	Pg. 51
Top three most common species surveyed	*Acer pseudoplatanus,* *Quercus robur,* *Betula pendula*	Pg. 51
Land uses where a greater percentage of surveyed trees were found	Forest or woodland, Residential, Park or greenspace	Pg. 49
Percentage of surveyed trees in DBH size classes	7–20 cm: 47% 20–40 cm: 36% 40–60 cm: 12% >60 cm: 5%	Pg. 57
Percentage of trees in good or excellent condition	52%	Pg. 59
Top pest and disease threat	Ramorum disease	Pg. 85

Estimated ecosystem service provision amount and value in 2022			
Avoided runoff	253,000 m^3 per year	£309,000 per year	Pg. 65
Pollution removal[1]	244 tonnes per year	£1.1 million per year	Pg. 68
Net carbon sequestration	6,942 tonnes per year	£6.3 million per year	Pg. 74
Total annual benefit		£7.7 million per year	
Carbon storage	338,000 tonnes	£307.6 million	Pg. 74
Replacement cost	Amenity value of all trees: £22.6 billion Structural value of all trees: £455 million		Pg. 82

[1] Pollution removal by trees and shrubs

Key Conclusions

- Wirral's tree population is dominated by ***Acer pseudoplatanus***. It represents 12% of the population, which exceeds the recommended 10% maximum for a single species. Owing to its population, large size, and dense foliage, *Acer pseudoplatanus* is currently the top species for delivery of many ecosystem services: avoided runoff, air pollution removal, carbon storage and carbon sequestration.
- Of the trees recorded in the survey ***Salix caprea*** supports the highest number of invertebrate species. Increasing the populations of *Salix*, *Ilex*, and *Crataegus* species would increase the provision of pollen, nectar, fruit, and seeds as food for wildlife.
- **Agricultural land** covers 30% of the study area but contains less than 3% of the trees. Increasing tree canopy cover on agricultural land by working with landowners to plant new trees could help Wirral achieve its target of doubling canopy cover by 2030 and could improve habitat provision, biodiversity, and nature connectivity.
- **Trees in private gardens** and on residential streets represent more than half of the trees people can see from their homes, but when asked about where trees make the greatest positive contribution, private gardens ranked second lowest. However, many people who responded to the survey were already planting trees in their garden or were keen to do so. Community engagement in a garden tree planting and care scheme could build the perceived value of private trees and provide opportunities for people to contribute environmental benefits to their neighbourhoods.
- The number of trees, tree canopy cover, and ecosystem service provision are lower in **areas of high deprivation**. There is an opportunity to target tree planting in these areas to ensure that everyone can benefit from the vital services trees provide. Respondents to the survey who live in the most

deprived areas of Wirral, and who are most affected by the lack of benefits provided by trees, are more likely to want more trees in their neighbourhood and are also underrepresented in the survey. **Seeking out their values and perspectives** about trees is vital to confirm the results from this study, and to target tree planting that delivers the benefits that are important to people.

- People valued management of trees to create a **nice place to live**, and to **contribute to clean air**. Many people said they had less time than they wanted to visit local woods and trees. Making space for woodlands and trees within urban neighbourhoods, so that people can pass through them on their way to school, work, and shopping, will help to improve access to the benefits these places provide. People living in areas with the highest deprivation are the least likely to visit trees and woods as often as they would like, so creation of woodlands and greenspaces in these areas could be especially important.
- The **diversity** of Wirral's tree population is lower than ideal. Local people expressed a preference for native species, and a mixture of conifer and broadleaf, evergreen and deciduous, and large and small trees. Diversifying Wirral's tree population will increase resilience to climate change and pests and disease, help to ensure continued provision of ecosystem services, and deliver social and cultural values to local people. However, effective diversification requires use of non-native species, so education is important.
- Two-thirds of people said they would like to become more involved with decision-making about trees, but fewer than a third said their voices were heard. More than half of people said they would be willing to be involved in **action to help trees**, such as watering trees in public, planting trees in public, planting trees in gardens, joining tree events, and joining community groups. There is a community of people who want to help, provided there are the right kinds of opportunities for different people.

1 Introduction

Urban forests create healthy and liveable urban places. Eighty-three percent of the UK's population live in urban areas (Government Office for Science, 2021). In towns and cities we may experience flash flooding, urban heat islands, air and noise pollution, limited access and connection to nature, poor biodiversity, and poor physical and mental health. Urban trees can provide an effective nature-based solution to these negative impacts of urbanisation (Davies et al., 2017).

Wirral is a place of contrast and diversity in both its physical characteristics and social demographics (Wirral Borough Council, 2009). The region comprises towns, industry, agriculture, woodland, coast, saltmarsh, and rural villages. The built-up areas of Wallasey, Meols, Hoylake, Birkenhead, Greasby, West Kirby, Caldy, Barnston, Bebington, Heswall, Neston, and Ellesmere Port cover 52% of the borough. Wirral has communities ranking among the most and least deprived in the country (Office for National Statistics, 2019).

In their ten-year tree strategy (Wirral Borough Council, 2020) Wirral has committed to doubling the tree canopy cover across the borough by planting 210,000 trees by 2030. To date, over 2,500 trees have been planted through the Urban Tree Challenge Fund and over 11 hectares of new woodland have been created as part of the Trees for Climate woodland creation programme, supported by the Government-led Nature for Climate fund. In addition, more than 40,000 trees have been planted with the help of Wirral communities since 2020 comprising garden trees, hedgerows, orchards and woodlands.

Wirral Borough Council declared an Environment and Climate Emergency in 2019 with the aims of reducing emissions of climate-damaging pollution, increasing resilience, and protecting and enhancing biodiversity, and have pledged action to ensure council operations would reach net zero for 2030. Wirral is internationally recognised through its Bronze Status Carbon Literacy.

The UK's largest urban regeneration project, Wirral Waters, is underway in a 500-acre brownfield site and former dockland. Elsewhere in the borough town centres and roads are being redesigned to improve active travel. These developments offer excellent opportunities to maximise space for trees and other green infrastructure, to ensure a wide range of benefits are provided to lots of people.

1.1 Ecosystem service provision

Ecosystem services are the direct and indirect benefits that people derive from nature. They can be categorised as:

- provisioning, such as food and raw materials
- regulating, such as carbon sequestration and water purification
- supporting, such as habitat for species
- and cultural, such as recreation, mental and physical health (MEA, 2005; UK NEA 2011).

Ecosystem services link humans and their wellbeing to the natural environment. They are essential to human life. Quantifying, and putting a monetary value on, ecosystem services provided by trees highlights their worth in urban and rural settings. In a time of prolonged budgetary constraints and increasing competition for space in the urban realm, monetising ecosystem services enables comparison with the cost and value of other potential uses of land. Trees are valuable in their own right and a monetary value placed on trees will always be an underestimate, but it provides an opportunity for the voices of those who champion trees to be heard.

This project examines only a sub-set of all the ecosystem services that trees provide. Table 1 lists the services considered here, and Table 2 gives examples of further ecosystem services that we cannot yet quantify or value.

Table 1. Ecosystem services measured as part of the project, and their significance to Wirral.

Ecosystem service	What urban trees do	Relevance to Wirral
Avoided surface water runoff	Tree canopies intercept rainfall and reduce the amount that reaches the ground. Trees take up water from the soil and their roots encourage infiltration. Together these functions reduce surface water flooding.	Wirral experienced serious flash flooding in September 2019, bringing major disruption to travel, homes, schools, and businesses. Extreme weather events like these will occur more frequently and with more intensity as our climate changes.
Air pollution removal	Trees can help reduce overall exposure to air pollutants harmful to human health, such as nitrogen dioxide (NO_2) through absorption or interception. Trees can also reduce local temperatures which reduces the rate at which some pollutants (e.g. ozone, O_3) are formed (Jacob & Winner, 2009).	Wirral launched a Clean Air Campaign in 2019 to increase public awareness of air pollution and encourage behavioural changes that can improve air quality. $PM_{2.5}$ concentrations in Wirral exceed the World Health Organisation exposure limit, but not the UK limit.
Carbon storage and sequestration	Trees absorb carbon dioxide for photosynthesis, which produces glucose. Glucose is used for respiration or growth. Growth results in storage of carbon in the tree's woody material. Trees can continue to store and sequester carbon throughout their lifetime.	Wirral council declared an Environment and Climate Emergency in 2019 and pledged to undertake measures to ensure council activities reach net zero by 2030. Wirral is the first Merseyside authority to be awarded Climate Literacy recognition.
Habitat provision	Trees are vital sources of food and shelter for a variety of flora and fauna. Trees in urban areas can boost people's engagement and feeling of connection with nature. Woodland trees can provide wildlife corridors to facilitate movement between sites.	The Wirral peninsula is home to a wide array of habitats and species. However there is a large amount of urban and agricultural land in Wirral which may not be supporting as many species as it could, and there are many isolated fragments of woodland that limit habitat connectivity.
Amenity and other social and cultural values	Visual amenity is the overall pleasantness of the views people enjoy of their surroundings (Landscape Institute, 2013). Trees are an essential component of visual amenity (Ministry of Housing, Communities & Local Government, 2021).	Wirral is a diverse region with wide ranging levels of deprivation, and both urban and rural communities. Trees in urban areas can improve equitable provision of amenity and wellbeing for all types of people.

Table 2. Ecosystem services provided by urban trees that were not measured as part of this project, and their significance to Wirral.

Ecosystem service	What urban trees do	Relevance to Wirral
Historic value	Trees can be a link to the past, creating a historical context to a place, and contributing to the local landscape character and sense of place.	Large urban regeneration programmes and active travel schemes are underway in Wirral. Planting trees as part of these developments can creates a link between old and new urban treescapes. Care and management to ensure new trees reach maturity will help them become the historical trees of the future.
Educational value	Engaging with nature can be a brilliant way of learning, for children and adults alike. Trees and woodlands present many opportunities to be used as educational tools to learn about the natural world.	Over 100 primary schools in Wirral are registered with Eco Schools, a national accredited programme, supported by Wirral Council. As part of their commitment to double tree canopy cover by 2030, Wirral organises free community tree-planting events.
Noise reduction	When planted densely in wide shelterbelts, trees can significantly reduce the noise and apparent loudness of passing traffic and other industrial noise.	Noise pollution has an impact on amenity, health, productivity, and the natural environment. Local sources of noise pollution include built-up areas (52% of Wirral) and the M53 motorway.
Temperature regulation	Trees can contribute to local cooling through transpiration and shading. Temperature regulation by trees is particularly important in towns and cities, to mitigate the urban heat island effect.	In the UK hot summers are expected to become more common (Met Office, 2022), with the temperature increase predicted to be between 3.7°C and 6.8°C (based on UKCP local 2.2km projections). Strategic tree placement could help to cool the local air temperature by 2–8°C (Forest Research, 2013).
Recreation	Green infrastructure, including trees, can lead to increased uptake in physical activity, and subsequently improve physical and mental health (Kondo, et al. 2018).	Adults and children in Wirral have relatively poor health compared to England. In addition, there are health inequalities between the least and most deprived communities. Access to green spaces can help to reduce these differences.

1.2 Social and cultural values

Access to trees has become increasingly important to people in recent years due to major societal issues including disconnection with nature, widespread mental health problems, inactive and sedentary populations with obesity, and environmental issues such as climate change, depletion of biodiversity and the loss of species. A large evidence base is growing on the benefits to physical and mental wellbeing, and the importance of this in terms of public health.

It is, therefore, important to explore how people perceive trees where they live, the benefits they provide, their spatial and equitable distribution across sections of the population, and how they differ across treescapes. This project has considered some of the many social and cultural values that people hold about trees. Results from such research have the potential to feed into resource management decisions, treescape creation and expansion decisions, and be used to inform solutions for improving engagement with, and benefits received from, trees, woods and forests across populations.

1.3 Project aims

- To gain a baseline understanding of the distribution and composition of Wirral's tree population
- To value some of the ecosystem services provided by Wirral's trees
- To gain understanding of the importance of Wirral's trees to local people

1.4 Using this report

This technical report provides detailed baseline information on the structure and composition of Wirral's tree population and the benefits it delivers. It may be used to help inform strategic thinking and future decision-making with regards to Wirral's tree resource.

This report has been produced for Wirral Borough Council, but can also be used by:

- People writing strategies and policies
- People involved in planning to incorporate resilient and sustainable tree cover into new and existing developments
- Landowners who are looking to increase tree cover on their land
- People who are interested in local trees for improving their own and others' health and wellbeing
- People interested in local nature conservation.

Limitations

- The v6 i-Tree Eco model provides a snapshot of the size, composition and condition of an urban forest. To be able to assess changes in the urban forest over time, repeated i-Tree Eco studies, or comparable data collection, would be necessary.
- i-Tree Eco uses air pollution data from regional air quality monitoring stations and the data used therefore represents an area-wide average, not localised variability.
- i-Tree Eco is a useful tool providing essential baseline data required to inform management and policy-making in support of the long-term health and future of an urban forest but does not report on these factors itself.
- i-Tree Eco demonstrates which tree species and size class(es) are currently responsible for delivering which ecosystem services. Such information does not necessarily imply that these tree species should be used in the future.
- Planting and management must not rely solely on i-Tree Eco results, but also be informed by:
    - Site-specific conditions, such as soil properties, and available growing space
    - The aims and objectives of the planting or management scheme
    - Local, regional and/or national policy objectives

- Current climate and future climate projections and associated threats; and
- Guidelines on species composition and size class distribution for a healthy resilient urban forest.

For further guidance, refer to the Urban Tree Manual (Defra, 2022a).

1.5 Further information

Further details on i-Tree Eco and the full range of i-Tree tools for urban forest assessment can be found at: www.itreetools.org.

To download reports on previous UK i-Tree Eco studies visit i-Tree Eco - Forest Research.

Engagement with trees in the urban environment create opportunities for members of the general public and community groups to become citizen scientists. Interested readers are referred to Treezilla: the Monster Map of Trees (www.treezilla.org).

2 Methodology

2.1 Social and cultural values methodology

This is the first i-Tree Eco study to include key characteristics of an urban treescape which can be measured and indicate or quantify a flow of potential social and cultural ecosystem services (SCES), or social and cultural values. The following characteristics were chosen on the basis that they could be combined with existing i-Tree Eco methodology, would improve calculation of amenity value, and could be integrated into the project design:

- Public visibility

  Viewing trees and other types of greenery have been linked with a variety of SCES including better physical & mental health, learning, and productivity. Having an understanding of the public visibility of trees may create opportunities to increase engagement with trees and raise the profile of trees as an essential component of communities.

- Public accessibility

  Broadly, greater access to trees means greater benefits for people including physical & mental health benefits. Understanding people's access to trees, in terms of perceived and physical ease of access and barriers preventing access, can help identify where accessibility might be improved.

- Location of trees in areas of deprivation

  Many potential social and cultural ecosystem services from trees (e.g. better physical and mental health) can benefit lower socioeconomic groups of people more than better off groups. Understanding the distribution of trees across levels of deprivation (IMD) can help identify inequality of services provided by trees and potential opportunities to remedy this.

To investigate the social and cultural values of trees in Wirral, data were collected via an online questionnaire of the public and via the tree surveyors. The survey questions were designed to cover a range of topics, some of which were based on previous work exploring public perceptions of urban trees (Ambrose-Oji et al., 2021). The topics in the questionnaire include:

- Perceptions of trees
- Preferences for trees
- Management of trees
- Action for trees
- Uses and values of trees

To obtain respondents the survey was shared on a number of online platforms and media (e.g., the Wirralview website and newsletter, and the Wirral council social media pages), between the 23rd August and 21st October. It is likely that respondents to the survey have an interest in trees, and that there is therefore an element of self-selection bias in the results.

Details of the methods used to analyse the results are given in Appendix A. Letters are used on graphs to denote statistical differences. If a category shares a letter (e.g. ‘a’ and ‘ab’) then they are not statistically different. Those categories with different letters (e.g. ‘a’, ‘b’ and ‘cd’) can be considered significantly different. Error bars on these graphs represent 95% confidence intervals.

Data pertaining to the three characteristics of public visibility, public accessibility, and location of trees in areas of deprivation were collected in the tree survey and in the people survey (Table 3).

Table 3. Visibility, accessibility, and deprivation data collected in the people survey and during the tree survey.

Variable	Tree survey	People survey
Public visibility	What is the public visibility of the tree? - Tree fully visible from at least one direction, on or immediately adjacent to public land - Tree clearly visible from a public location, but with somewhat reduced visual contribution to public amenity - Tree visible from a public location, but with significantly reduced visual contribution to public amenity	Thinking about any trees you can see looking out from your home, can you see at least three trees? Of the trees you can see from your home, where are they? - Residential streets - Roadsides and roundabouts - Parks and recreation/sports grounds open to the public - Public service and amenity areas - Private gardens - Community gardens and allotments - Urban woodlands - Railway lines - Canal and riverbanks - New housing developments
Public accessibility	What is the public accessibility of the tree? - Tree publicly accessible - Tree not publicly accessible	
Physical accessibility	Describe the access route to the tree: - Road (motor vehicle or other vehicle such as bicycle) - Paved or tarmac footway - Other smooth footpath - Surfaced cycleway - Natural or semi-natural footpath or bridleway - No path - Other (please specify)	How often do you visit local trees/woods? Is it as often as you would like to? Which of the following prevent you from visiting your local trees/woods as much as you would like to? - Difficult to travel - Too far away - Poor infrastructure - I do not feel safe there - Local trees/woods are dirty - Local trees/woods are unmanaged - Local trees/woods are fenced off - I don’t have enough time
Location of trees in areas of deprivation	Sampling stratified by IMD quintile	Respondents asked for first half of postcode

2.2 Sampling

This i-Tree Eco study takes a random sample approach to data collection. Sampling locations called plots (11.3 metre radius circles) are distributed across the area of interest, and data is collected in each plot. The data collected in the plot is representative of the whole study area and can be extrapolated to provide information on the total number of trees, the ecosystem services they provide, and more.

In a truly random sample plots are not necessarily distributed evenly across the geographic area and can clump together in small areas. In the heterogeneous urban environment, with a wide variety of land uses characteristics, this can lead to over- or under-representation of some areas in the data. To minimise this effect, a grid was overlain on the study area boundary, and a plot was placed randomly inside each grid square. The grid was constructed to ensure that the sampling density is appropriate to the study, in this case 250 plots across the study area, resulting in one plot every 63 hectares (see Table 8 for comparison with other projects). One backup plot was also placed randomly in each grid square, to be used in the event of the primary plot being inaccessible (see Figure 45 in Appendix A).

2.2.1 Study area

The study area for this project is the Wirral Metropolitan District, including urban and rural regions, covering 15,705 hectares (Figure 1).

2.2.2 Stratification

One focus of this study is the social and cultural values of trees, and the distribution of benefits provided by trees across Wirral.

The English indices of multiple deprivation measure relative deprivation in small areas called lower super output areas (LSOA). The indices measure seven different facets of deprivation:

- Income deprivation
- Employment deprivation
- Education, skills and training deprivation
- Health deprivation and disability
- Crime
- Barriers to housing and services
- Living environment deprivation

The index of multiple deprivation (IMD) is a single number metric combining these facets. The lower the number, the more deprived the area relative to other areas in the country. The data are released by National Statistics for the Ministry of Housing, Communities & Local Government.

The Wirral i-Tree Eco study has been stratified by IMD. This means the study area was divided into distinct regions before the fieldwork was undertaken, enabling analysis of data and comparison of results across areas with different levels of deprivation.

The IMD data used here are from the 2019 English indices of deprivation (Office for National Statistics, 2019), downloaded from the Open Geography Portal[2]. LSOA shapefiles were clipped to the study area boundary, joined to IMD data, and classified into five ranks (quintiles), with quintile 1 being the most deprived, and quintile 5 being the least deprived. Table 4 gives details of the quintiles and the plots that were surveyed.

[2] https://geoportal.statistics.gov.uk, under the Open Government License v3.0.

Table 4. Total area, number of plots, and plot density of each stratum (IMD quintile).

IMD quintile	Area (hectares)	Number of surveyed plots	Plot density (1 plot per [] hectares)
1	2,972	47	63
2	1,562	24	65
3	2,702	47	57
4	5,165	79	65
5	3,306	49	67

Figure 1 shows the distribution of plots across the study area, and Figure 2 shows the IMD quintiles. Note that the quintiles are not continuous.

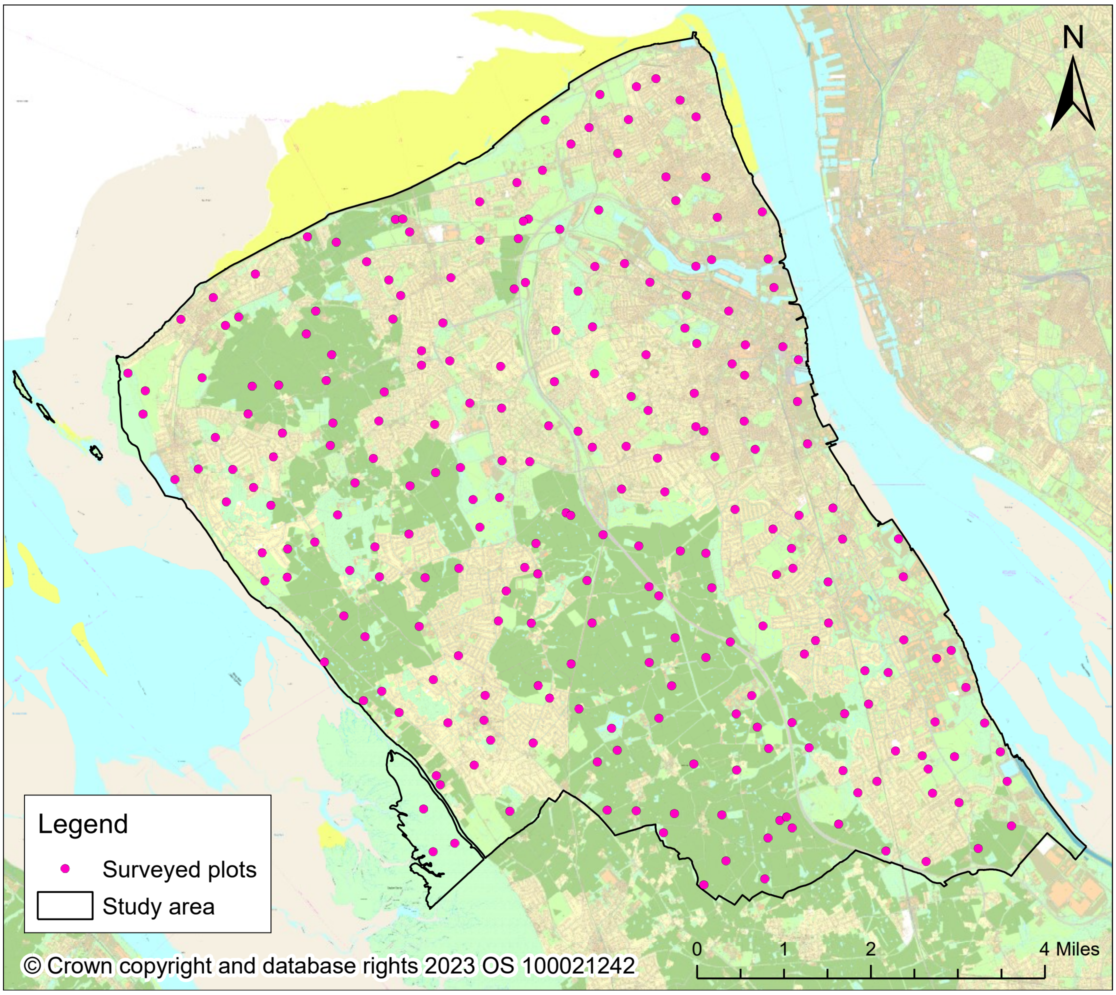


Figure 1. Map of Wirral study area and surveyed plots.

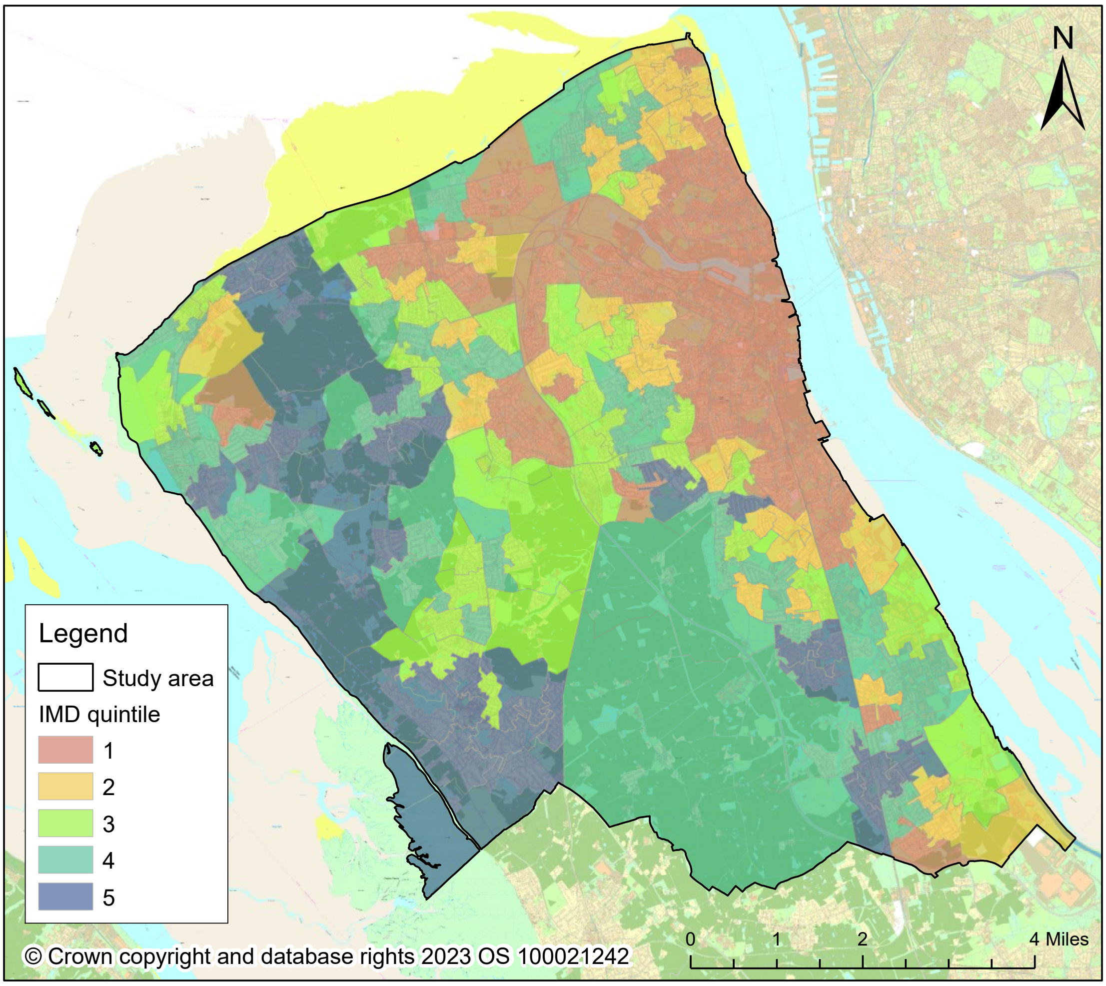


Figure 2. Map of IMD quintiles in Wirral.

2.3 Field data collection

Not all plots were accessible to surveyors. Their distribution across the study area means they land on buildings, woodlands, water, parks, streets, and more. This variety of ground covers and land uses is an important aspect of an i-Tree Eco survey. When a plot was inaccessible, surveyors switched to the backup plot. In the event that the backup was also inaccessible, the plot was removed from the survey. In total 246 plots were surveyed. Table 5 lists the data collected about each plot.

Table 5. Plot data collected in the survey

Variable	Description
Date	Date
Surveyor name(s)	Names of surveyors
Photographs	Photographs of plot in four directions from centre
% Tree cover	Percentage of total plot overhung by tree canopies
% Shrub cover	Percentage of total plot covered by shrubs
Ground covers	Types of ground cover present in plot, and their percentages
Land uses	Types of land uses present in plot, and their percentages
Shrub details	Shrub height, species, amount missing
Comments	Comments about plot and trees

Shrubs were defined as woody plants with a stem diameter smaller than 7 cm, and a height at of at least 1 metre. Smaller shrubs and other types of plant in the plot were recorded as ground cover.

Trees were defined as woody plants with a stem diameter at breast height (DBH) (here defined as 1.5 metres) of at least 7 cm. All trees whose trunks were entirely inside the plot boundary were surveyed. Trees located on or near the plot boundary were surveyed if at least half of their trunk diameter was inside the boundary. Trees whose trunks were outside the boundary, but whose crowns overhung the plot, were included in plot tree cover. Table 6 lists the data recorded about each tree in the survey.

Table 6. Tree data collected in the survey.

Variable	Description
Tree ID number	ID number for each tree in plot, starting at 1 for each new plot
Land use	Which land use is the tree in
Species	
DBH	Diameter at breast height (1.5 metres)
Height to crown base	Height from ground to base of crown, in metres
Height to live top	Height from ground to highest live part of tree, in metres
Total height	Height from ground to highest part of tree
Live crown width (N-S)	Width of live parts of crown in north-south direction, in metres
Live crown width (E-W)	Width of live part of crown in east-west direction, in metres
Crown light exposure	Sides of the crown exposed to direct or indirect light (0 to 5)
% Crown missing	Percentage of the crown volume that is not occupied by leaves and branches, due to pruning, dieback, defoliation, uneven shape, dwarf or sparse leaves, taking into account species or cultivar characteristics
% Crown in good condition	Percentage of the crown volume without dieback, not including normal, natural dieback such as caused by shading in the lower part of a canopy
% Impervious ground cover below canopy	Percentage of ground under canopy covered by impervious surface such as tar
% Shrub cover below canopy	Percentage of ground under canopy covered by shrubs
Life expectancy	Life expectancy of tree in years (in six bands covering less than five years to more than 80 years)
Places visible from tree	Types of buildings and places visible from the tree
Public accessibility	Tree classed as publicly accessible or not publicly accessible
Surface type of access route	Type of surface (e.g. natural, smooth) on routes people could use to access the tree (e.g. footpath, road)
Public visibility	Tree classed as Fully visible from a public place, to Effectively invisible from a public place

2.4 Calculations

2.4.1 Replacement cost and amenity value

Replacement cost is an estimate of the cost of replacing an existing tree, should it be lost due to development, damage, or other reasons for removal. i-Tree Eco provides cost estimates for the like-for-like replacement of trees in urban areas based upon the CTLA (1992) valuation method. See Appendix A for more information.

Urban trees also provide significant amenity value. An amended version of the Capital Asset Value for Amenity Trees (CAVAT) Full Method (Doick, et al. 2018) was also used to assess the value of Wirral's trees. CAVAT values are based upon tree size (trunk diameter) and are depreciated for attributes that impact the tree's contribution to amenity. CAVAT includes a Community Tree Index (CTI) factor which adjusts the value to take into account greater amenity associated with higher population density, using official population figures. The CAVAT value relates to the replacement cost of the tree as an amenity asset, rather than as a structural asset (as per CTLA) and has been used by many councils across the UK to support planning decisions. An amended version of the Full Method was used in this study, including measurements of public visibility for improved accuracy. See Appendix A for more details.

2.4.2 Pests and diseases

The susceptibility of Wirral's trees to pests and diseases was assessed using information on the number of trees within pest/pathogen host groups and the prevalence of the pest/disease within Merseyside or the UK. A risk matrix was used to determine the number of trees that could be impacted by each pest/disease should they become established within the local area, as well as the probability of establishment.

2.4.3 Habitat

Trees and shrubs provide valuable habitats and food for many species, including insects, birds and mammals, as well as non-vascular plants such as moss. An analysis of the number of insects associated with British trees (Kennedy and Southwood, 1984), and relative scores of the value of different tree species for provision of blossom, pollen, fruits, and seeds to UK wildlife (Alexander et al., 2006) were used to examine the relative biodiversity value for urban trees.

Table 7 summarises the calculations for ecosystem services.

Table 7. Summary of calculations

Variable	Calculated from
Number of trees	Total number of trees; an estimate based on an extrapolation from the sample plots. See Appendix A for details of sampling statistics.
Tree canopy cover	Total tree cover extrapolated from tree cover (%) measured within plots.
Pollution removal value	The amount of pollution removed each year by trees. Value is based on the UK social damage costs (UKSDC) where available: £6,385 per tonne NO_x (nitrogen oxides), £13,026 per tonne SO_2 (sulphur dioxide), £73,403 per tonne $PM_{2.5}$, and a $PM_{2.5}/PM_{10}$ conversion factor of 0.71 (Defra, 2022b)
Avoided runoff	The amount of water not entering the water treatment system because of the presence of trees. Valuation uses the household foul drainage volumetric charge (£1.221 per m^3; United Utilities, 2022).
Carbon storage and sequestration values	The amount of carbon currently stored in the trees, and the amount absorbed every year. The 2022 value is £248 per tonne of CO_2e (BEIS, 2021).
Replacement cost	The value of the trees based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree), determined within i-Tree Eco according to the CTLA (Council of Tree and Landscape Appraisers) v9 method.
Amenity	The cost of replacing the public amenity that Wirral's trees provide, using an amended version of Capital Asset Value for Amenity Trees (CAVAT) Full method.

2.4.4 Canopy cover

Canopy cover was assessed using data from the Forest Research Canopy Cover Webmap[3]. Contributors to the webmap undertake assessments using the i-Tree Canopy tool[4], in which an aerial image of an electoral ward is overlain with randomly-placed points, which the user classifies as lying over a tree, or non-tree. Point data from ward-level assessments (Figure 3) were merged and clipped to the study area, then spatially joined to the IMD quintile boundaries. Canopy cover in each IMD quintile was calculated as the number of points classified as "tree" divided by the total number of assessment points.

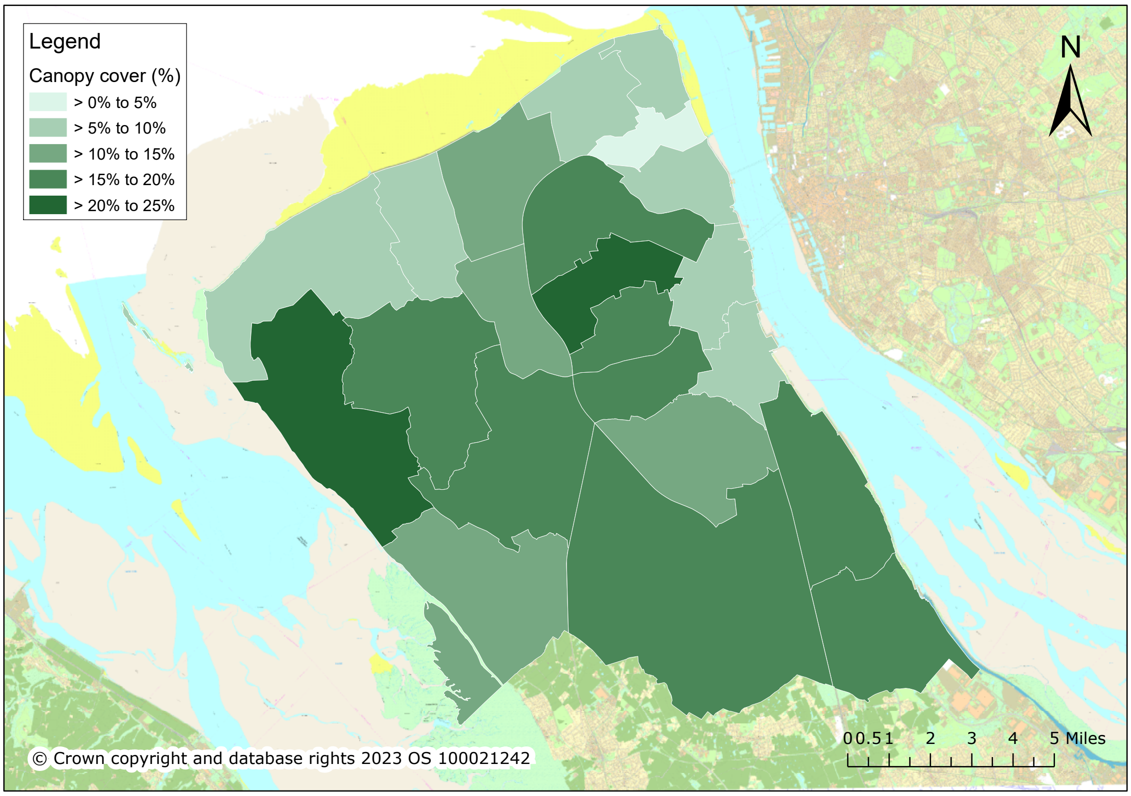


Figure 3. Ward-level canopy cover in the study area, from the Forest Research Canopy Cover Webmap. Map produced using ESRI ArcMap v10.

3 https://www.forestresearch.gov.uk/research/i-tree-eco/uk-urban-canopy-cover/
4 https://canopy.itreetools.org/

3 Results and Discussion

This section of the report presents the results of the i-Tree Eco survey of Wirral's tree population, and the survey of local residents. Table 8 compares the Wirral study to projects in other UK locations.

Table 8. Details from Wirral's i-Tree Eco survey compared to five other UK surveys.

	Wirral	Belfast	Derby	Vale of Glamorgan	Greater London
Study area size (ha)	15,707	13,338	7,801	3,609	159,064
Number of trees	1,022,000	809,000	255,000	143,000	8,421,000
Plot density (one per […] ha)	64	43	22	22	221
Canopy cover (ha)	2,168	3,080	645	469	22,326
% Tree canopy cover	13.8%	14.5%	8%	13%	14%
Average number of trees per ha	65	61	33	40	53

3.1 Social and cultural values

This section describes selected results from the people survey and compares these to results from the i-Tree Eco survey. Relevant results from the people are also included in later sections and discussed in the context of the i-Tree Eco results.

3.1.1 Participant characteristics

In total, we achieved a survey sample size of 304, of which around two thirds (62.6%) identified as Female, roughly a third Male (35.1%), with the remaining preferring not to say (2.3%). Collection of postcode data enabled classification of the respondents' location into one of five IMD quintiles, with quintile 1 being the most deprived and quintile 5 being the least deprived. The sample had roughly equal number of respondents from each of the IMD quintiles with slightly higher proportions in quintiles 2 and 3. Table 9 gives estimated population data for the five quintiles, showing that quintile 1 has approximately double the population of the other quintiles. This suggests people who live in the most deprived area of Wirral are under-represented in the people survey results. The average age of our sample was 56.7. The overwhelming majority of respondents has access to a private garden, with far lower numbers having access to community or shared gardens. Three percent of respondents had no access to a garden of any type.

Table 9. Population data for each IMD quintile and the study area.[5]

IMD quintile	Population	Population density / people per km^2
1	116,267	3,912
2	54,451	3,486
3	52,188	1,931
4	59,353	1,149
5	42,077	1,273
Study area	324,336	3,912

3.1.2 Public visibility

Figure 4 shows the public visibility of trees surveyed in each IMD quintile. **More deprived areas** have a higher proportion of trees that are **less publicly visible**, and which therefore make a lower contribution to visual amenity.

[5] Data source: English indices of deprivation 2019.

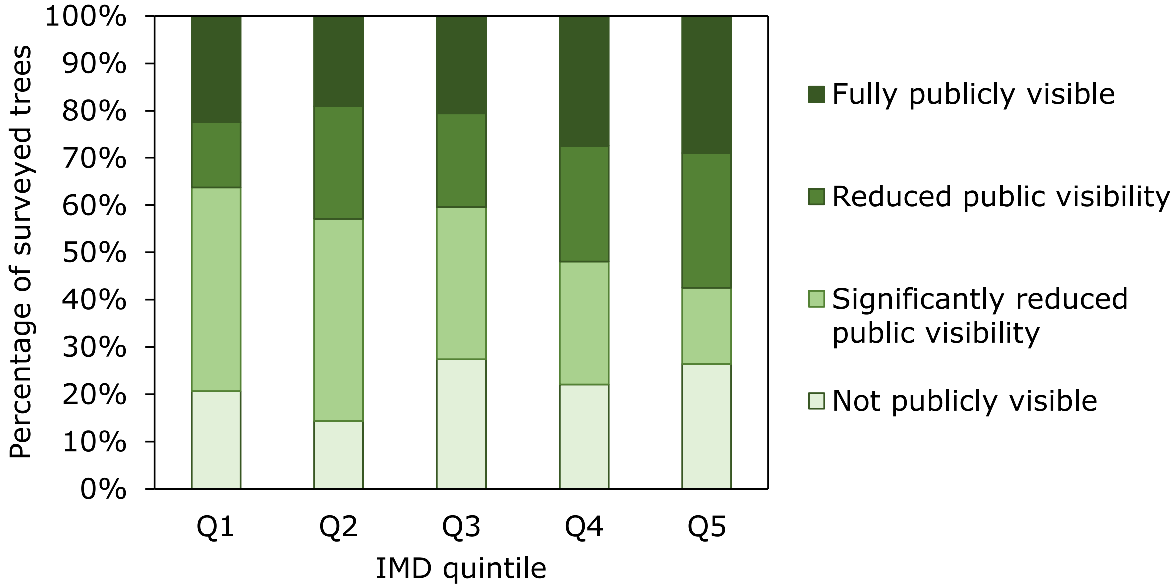


Figure 4. Public visibility of surveyed trees in IMD quintiles (strata). Surveyed trees only; data not extrapolated to stratum areas.

Every urban area is different, and it is difficult to set a single target for urban greenness that is appropriate to every location. However, broad guidelines can be very useful in highlighting where more provision of urban greenspace, including trees, is required. The 3-30-300 rule (Konijnendijk van den Bosch, 2021) is one such guideline. The rule states that cities should aim for the following:

- Everyone should be able to see at least three trees of a decent size from their home.
- Every neighbourhood should have 30% tree canopy cover.
- People should have accessible greenspace within 300 metres of their home.

Looking at the people survey data, **85% of respondents** said that they were **able to see three or more trees** looking out from their home. This differed according to the level of deprivation of the area the participant lived in, although the differences are not statistically significant (Figure 5).

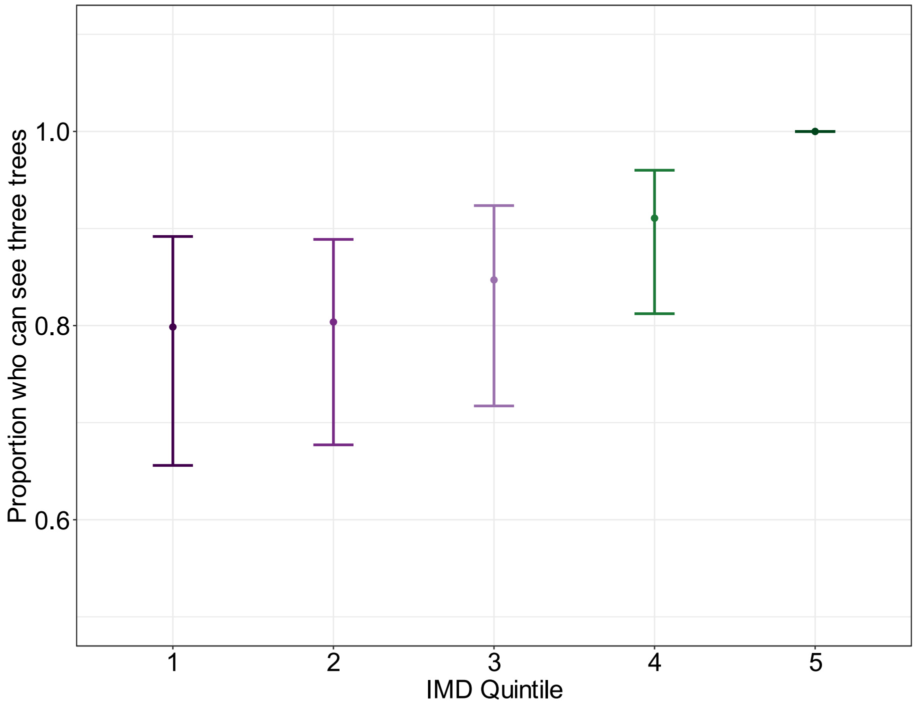


Figure 5. Proportion of survey respondents in each IMD quintile who could see three trees from their home.

Those living in the most deprived region were least likely to be able to see three trees; however, 80% of participants in the most deprived regions were still able to see three trees from their home. The majority of participants could see trees in private gardens or on residential streets but were least likely to see trees along canals and riverbanks (Figure 6). This finding highlight that for the communities that can see them, **trees in private gardens and residential streets** make an important contribution to visual amenity and could be a focus for public supported planting and maintenance efforts.

None of the areas in the study had tree canopy cover approaching 30%; the highest canopy cover is found in quintile 5 (17%), the least deprived area. A spatial study using a geographic information system (GIS) can provide information on the distance between where people live and their nearest accessible greenspace.

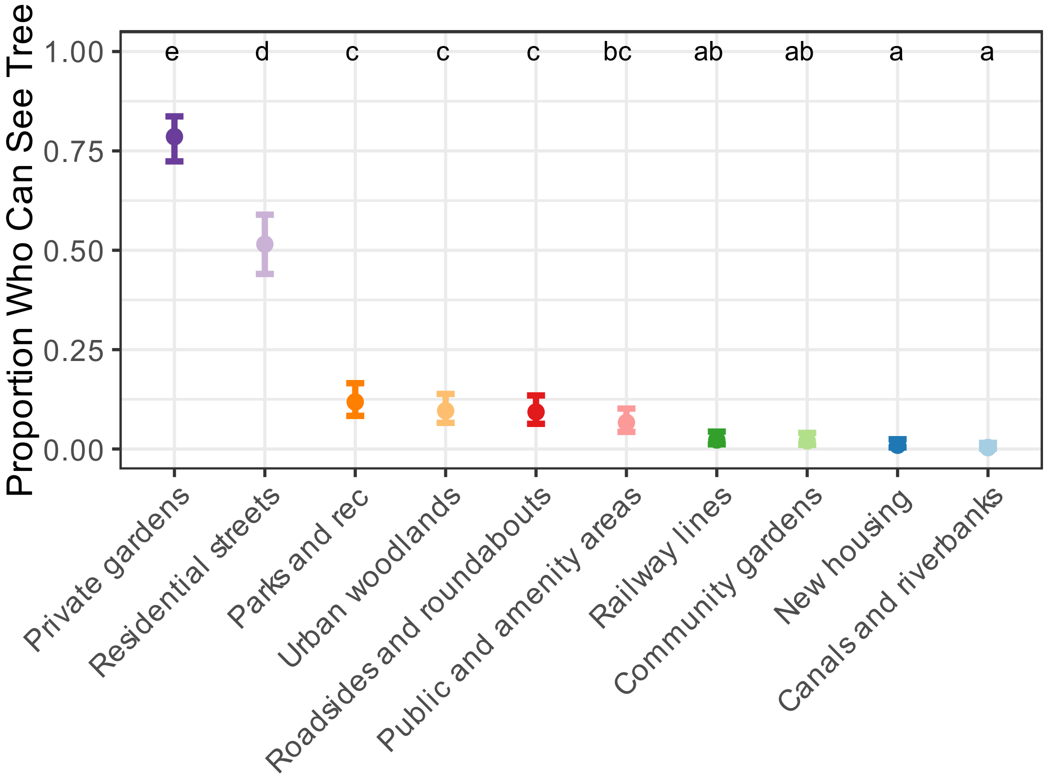


Figure 6. Tree visibility across different locations. Data from questionnaire survey.

3.1.3 Accessibility

Figure 7 shows the public accessibility of the trees surveyed in each IMD quintile. This metric differs from public visibility because people may receive different benefits from being in close proximity to trees, compared to being able to view them from a distance. Trees in publicly accessible parks and greenspace, along roads and streets, in the grounds of public buildings, and other places where the surveyors did not require permission for access, were judged to be publicly accessible. Trees in private gardens, in schools, on farmland without public rights of way, and in other private land uses where permission was required for access, were judged to be publicly inaccessible. In general, the more deprived areas of Wirral have a lower proportion of publicly accessible trees. **Quintile 2 has the highest proportion of publicly accessible trees**, which may be explained by its high proportion of parks and greenspace (see Figure 20).

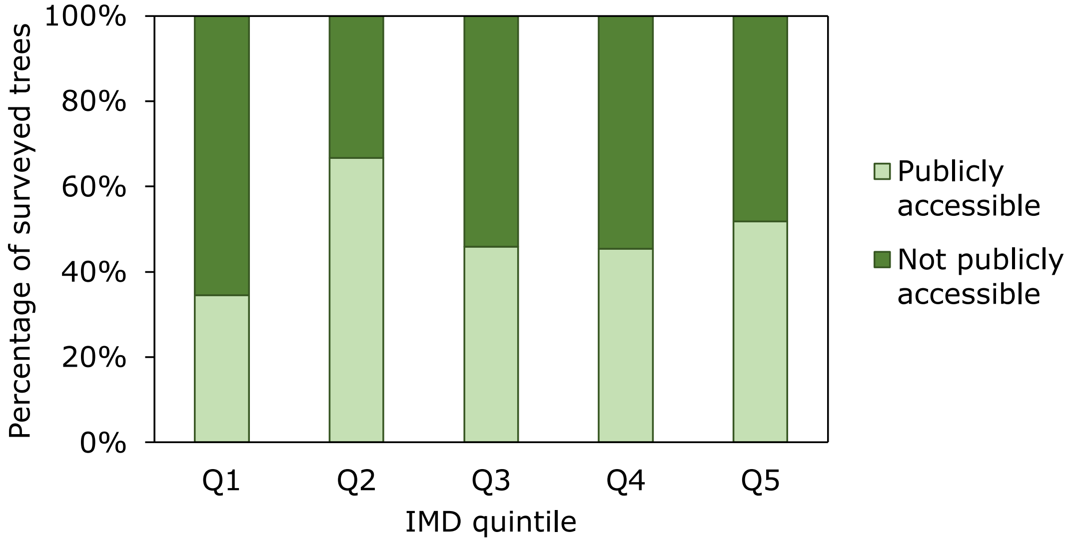


Figure 7. Public accessibility of surveyed trees in IMD quintiles. Surveyed trees only; data not extrapolated to stratum areas.

Access to trees can result in improved quality of life but the nature of access routes may be a barrier to some people. Figure 8 shows the surface types of access routes to the surveyed trees in the whole study area. Over 60% of the surveyed trees were accessed by a natural or semi-natural footpath or bridleway, suggesting that access for people with reduced mobility might be restricted for most of the trees surveyed. Fewer than 20% of the trees surveyed were accessible by a paved, tarmac, or other smooth footway.

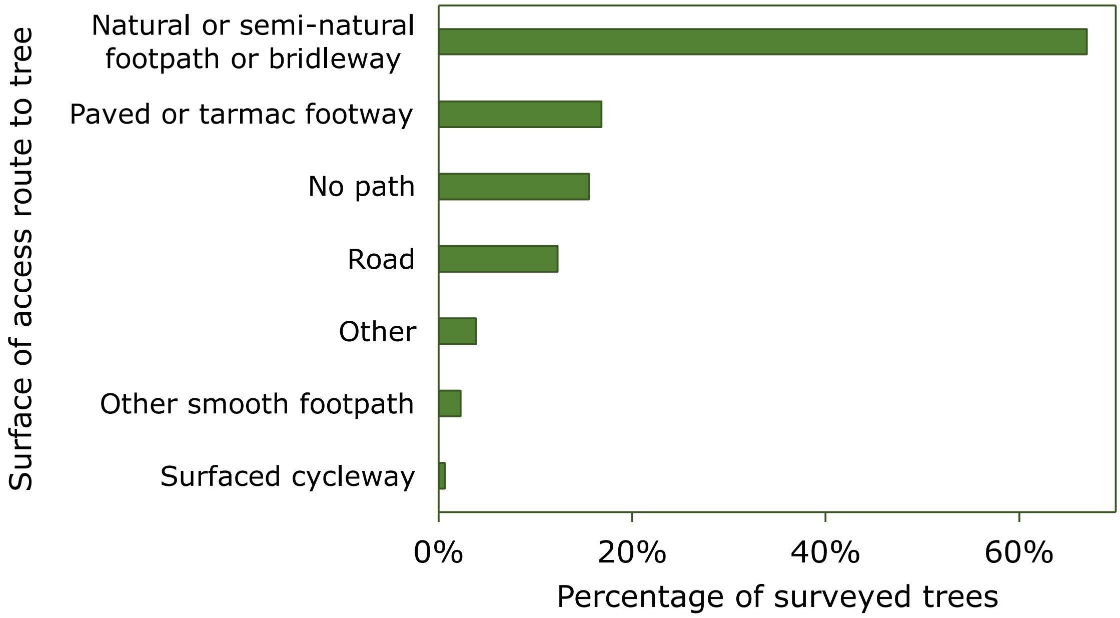


Figure 8. Surface types of access routes to surveyed trees. Surveyed trees only; data not extrapolated to stratum areas.

The people survey asked participants about barriers to visiting local trees and woods. Fifty eight percent of participants said that they were able to visit their local trees and woodlands as often as they would like. This differed according to IMD quintile (Figure 9). Participants living in more deprived areas were less likely to say that they visited local woods as often as they liked. Sixty percent of participants living in the most deprived areas were not able to visit local woods and parks as often as they like, compared to only 33% of participants in the least deprived areas (quintile 5). Ninety four percent of respondents said that they did not find it difficult to travel to their local trees and woods. The main barrier to access to trees and woods was a lack of time (18%, Figure 10).

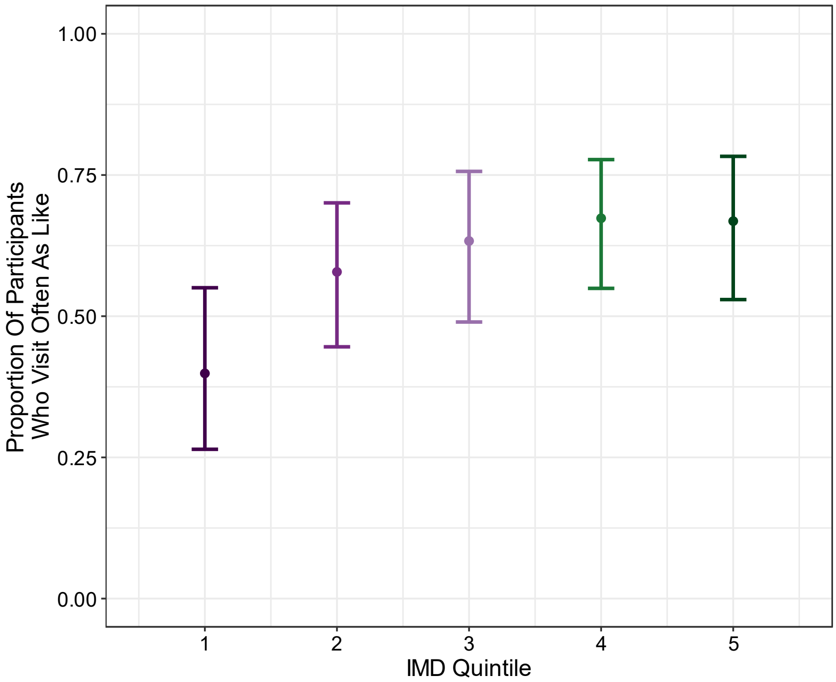


Figure 9. Proportion of respondents to the survey in each IMD quintile who visit trees and woods as often as they would like.

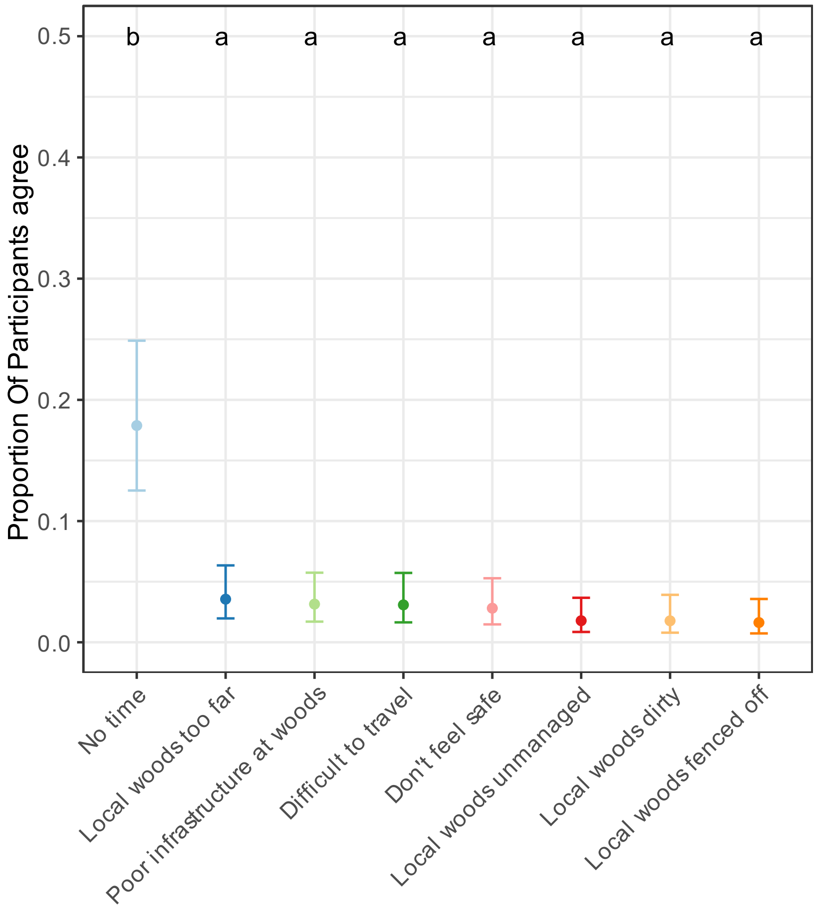


Figure 10. Reasons given by respondents to the survey for not being able to visit woods and trees.

3.1.4 Index of multiple deprivation

Figure 11 shows the canopy cover, and the percentage of land not built-up, in each IMD quintile and in the study area overall. In general, **more deprived areas of Wirral have more built-up land and less tree canopy cover**, and therefore lower provision of benefits from trees. IMD quintiles 1 and 2 have lower canopy cover than the study area average (13.4%).

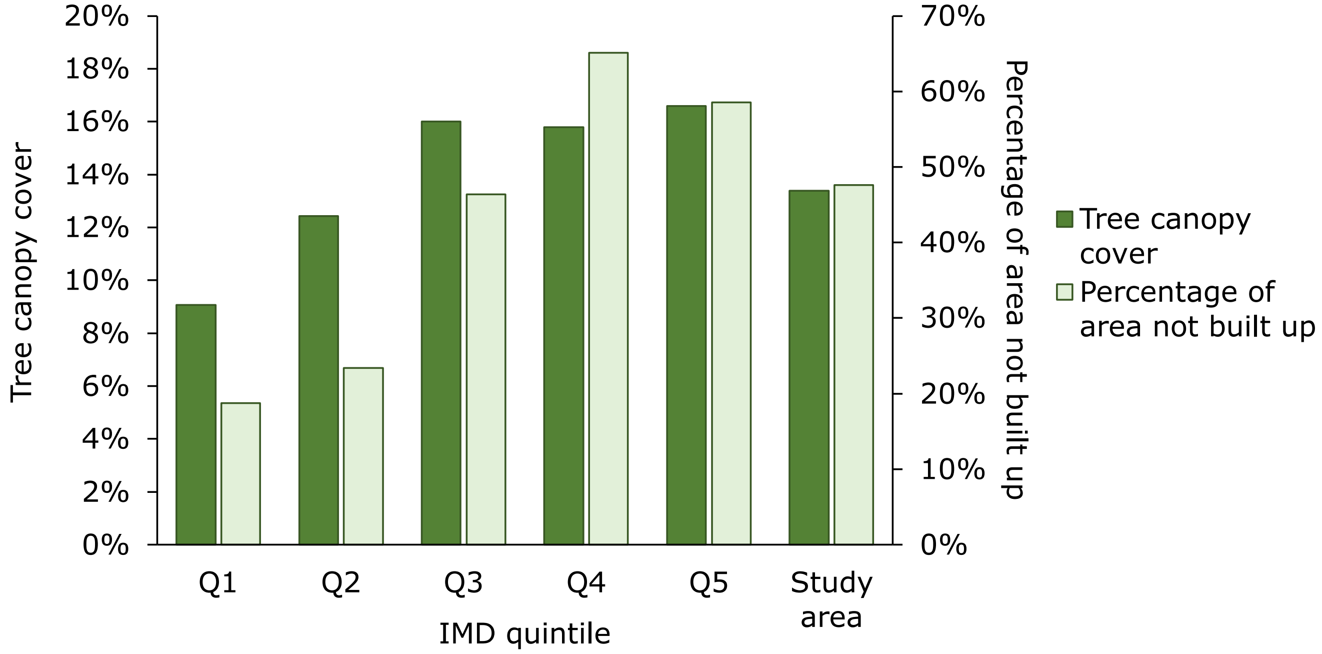


Figure 11. Tree canopy cover and percentage of land area not built up in each IMD quintile and in the study area.

Survey respondents were more likely to think there were too few trees in Wirral rather than too few trees in their street (Figure 12). This differed according to IMD quintile (Figure 13). **People living in areas of highest deprivation (quintiles 1 and 2) were more likely to think there were too few trees**, and trees taller than their first floor window, in their street. People living in areas of low deprivation were less likely to think there were too few trees in their streets. This suggests that the expectation and desire for trees on streets is the same regardless of which quintile people live in, but that the provision is different and is noticed by residents.

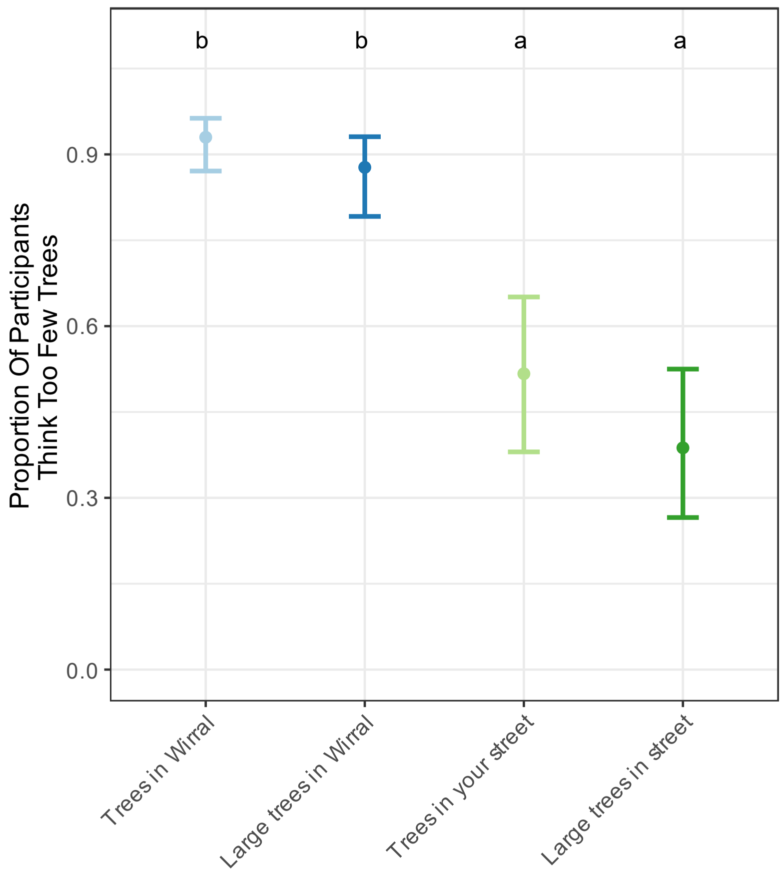


Figure 12. Public perceptions of tree cover in street and in Wirral. Data from questionnaire survey.

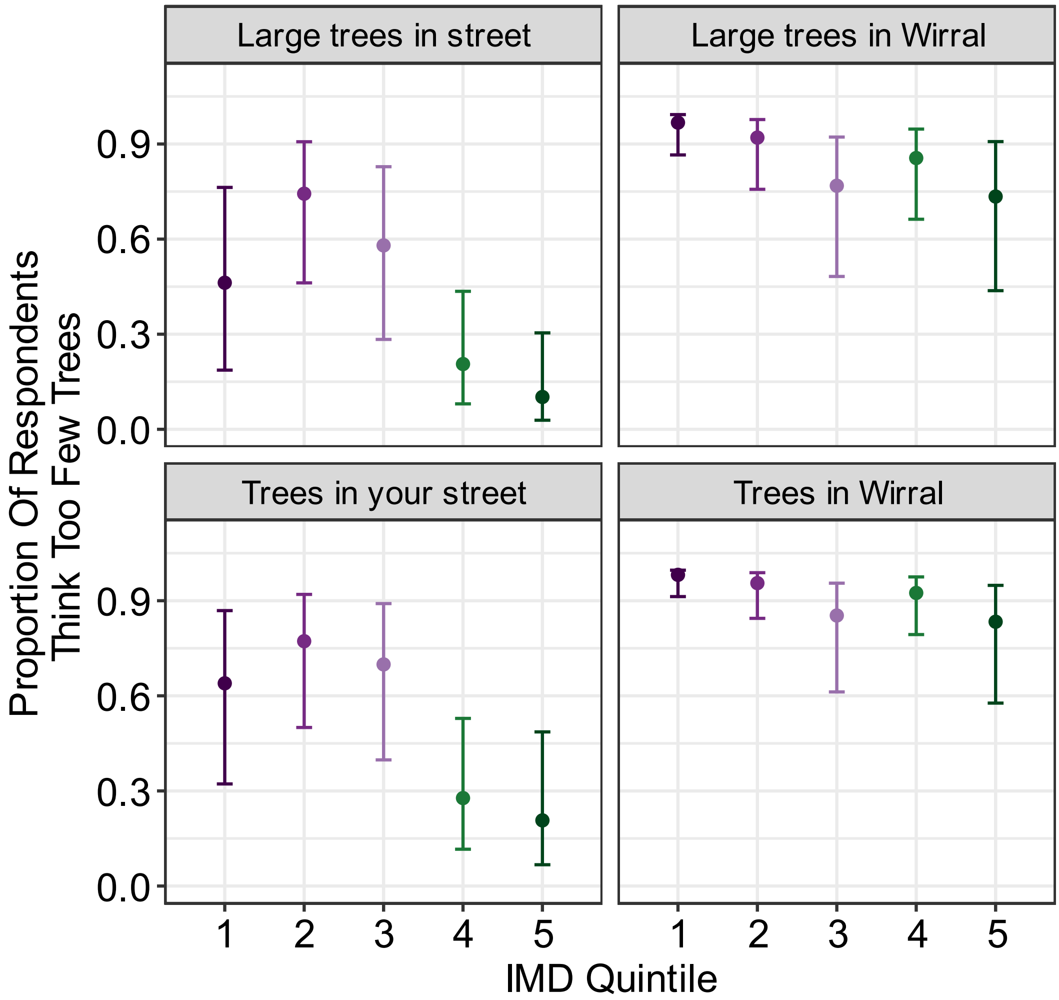


Figure 13. Differences in perceptions of tree cover across IMD quintiles. Data from questionnaire survey.

Figure 14 shows the estimated number of trees per hectare, and the area of land that is not built-up, in each IMD quintile. The more deprived areas of Wirral have fewer trees per hectare. Apart from quintile 4 there appears to be a strong relationship between the amount of land that is not built-up, and the number of trees per hectare. Quintile 4 has the highest proportion of land that is not built up, and also a high proportion of farmland compared to the other quintiles (see Figure 20). Farmland covers 40% of the survey area but contains just 3% of the trees.

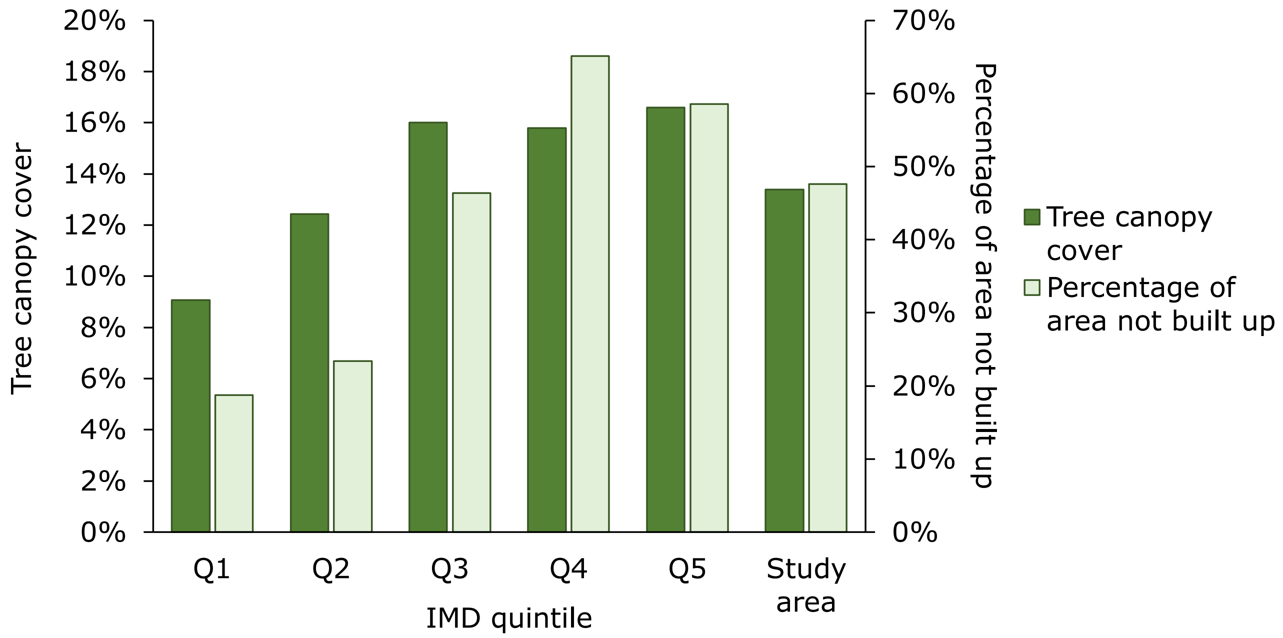


Figure 14. Estimated number of trees per hectare, and the percentage of land area not built-up, IMD quintile and in the study area.

Figure 15 shows the percentage of surveyed trees classified as large according to height (greater than 12 m), canopy spread (greater than 10 m), and DBH (greater than 60 cm). **More deprived areas of Wirral have a lower percentage of large trees**. Large trees provide a disproportionate amount of benefit to people and ecosystems (Hand et al., 2019c) and are an essential component of a healthy urban forest.

3.1.5 Action for trees

Survey respondents were asked to rate the importance of a variety of management aims for trees in their neighbourhood and Wirral. People generally thought that managing trees to reduce their potentially negative impacts (such as subsidence, leaf drop or pollen) was less important than managing to increase their positive impacts such as **creating a nice place to live and contributing to clean air** (Figure 16).

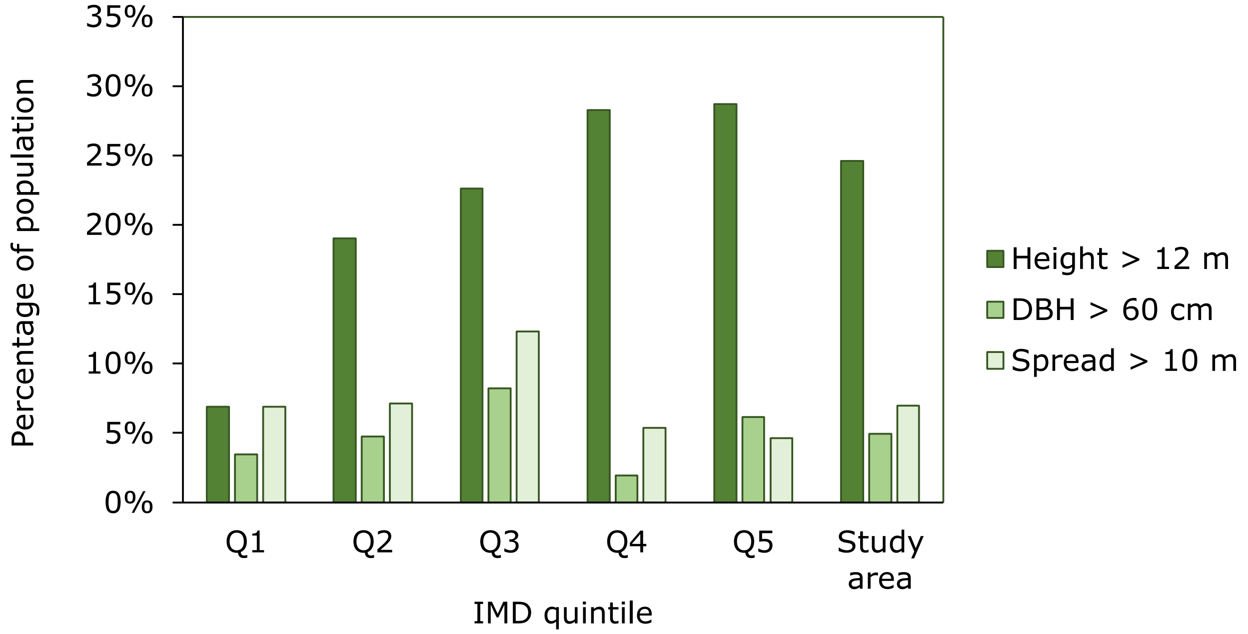


Figure 15. Large trees, according to height, DBH, and spread, in each of the IMD Quintiles in the survey. Surveyed trees only, not extrapolated to stratum areas.

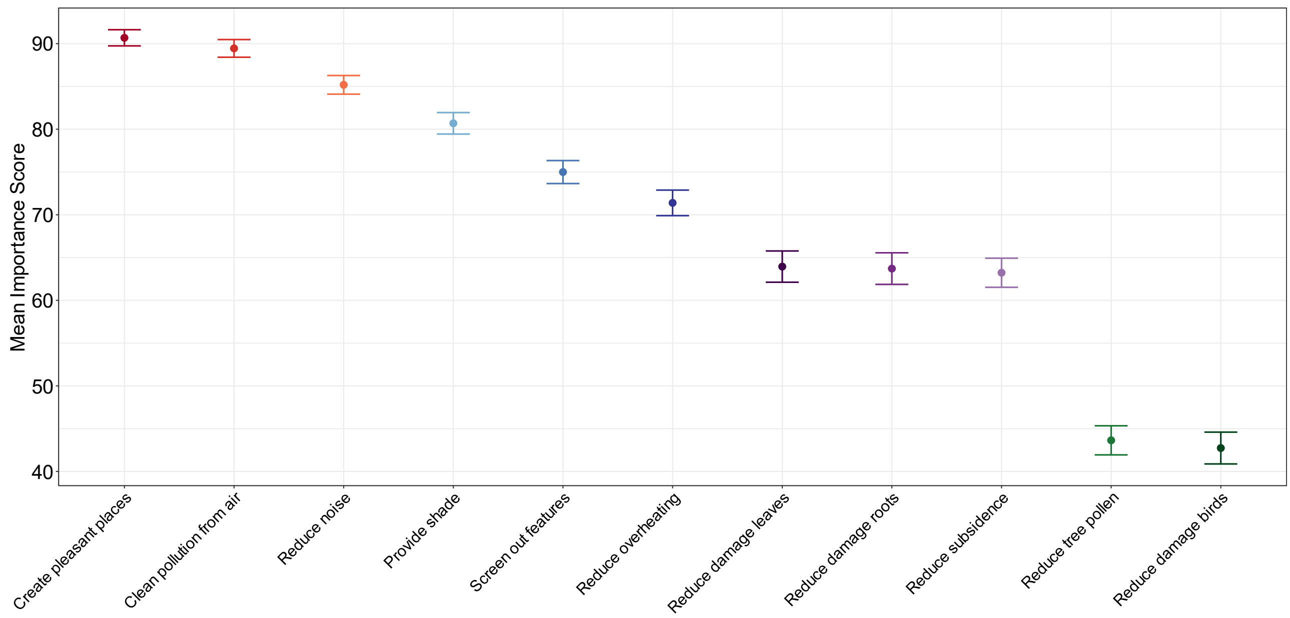


Figure 16. Mean importance scores survey respondents gave to the aims of tree management in their neighbourhood and in Wirral.

Survey respondents were asked a variety of questions about how involved they feel they are in the management of trees. Most respondents indicated that they wanted to get more involved with decision making around local trees and around one in two said that they knew who to contact if a tree in their neighbourhood was causing annoyance (Figure 17).

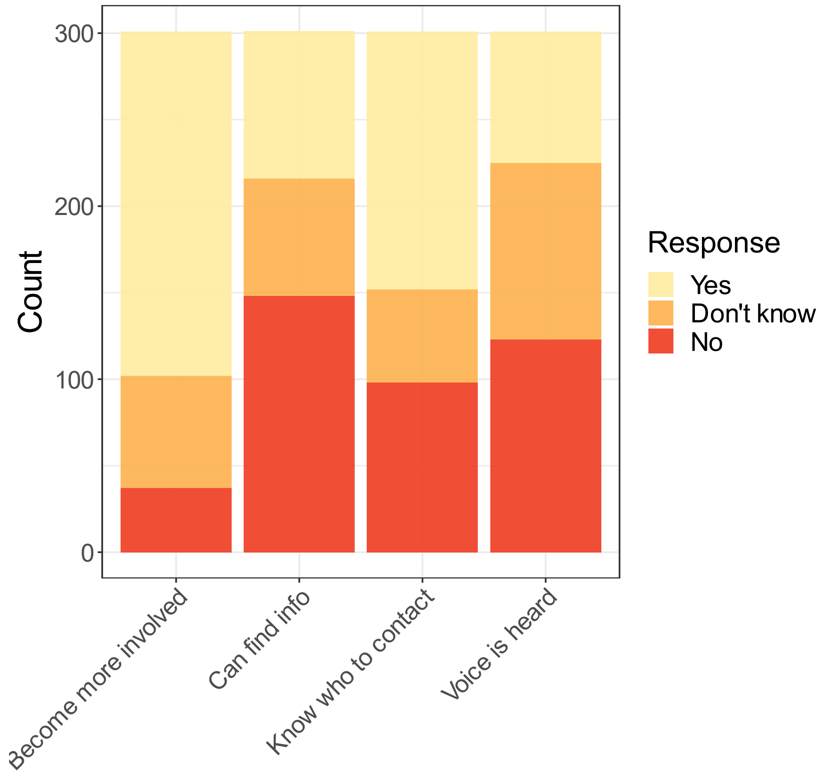


Figure 17. Survey responses to questions around the management of trees.

Survey respondents were asked about their current and potential involvement in a range of activities relating to trees. Participants were most likely to say that they had - or would be willing to - **plant trees in their own garden**. They were least likely to say they would be interested in becoming a tree warden (Figure 18).

Respondent age was associated with the willingness to perform actions for trees and this differed according to the action. Older people were more likely to donate to tree charities or contact MPs/councils about tree management. Younger participants were more likely to say they would plant and water trees in public places.

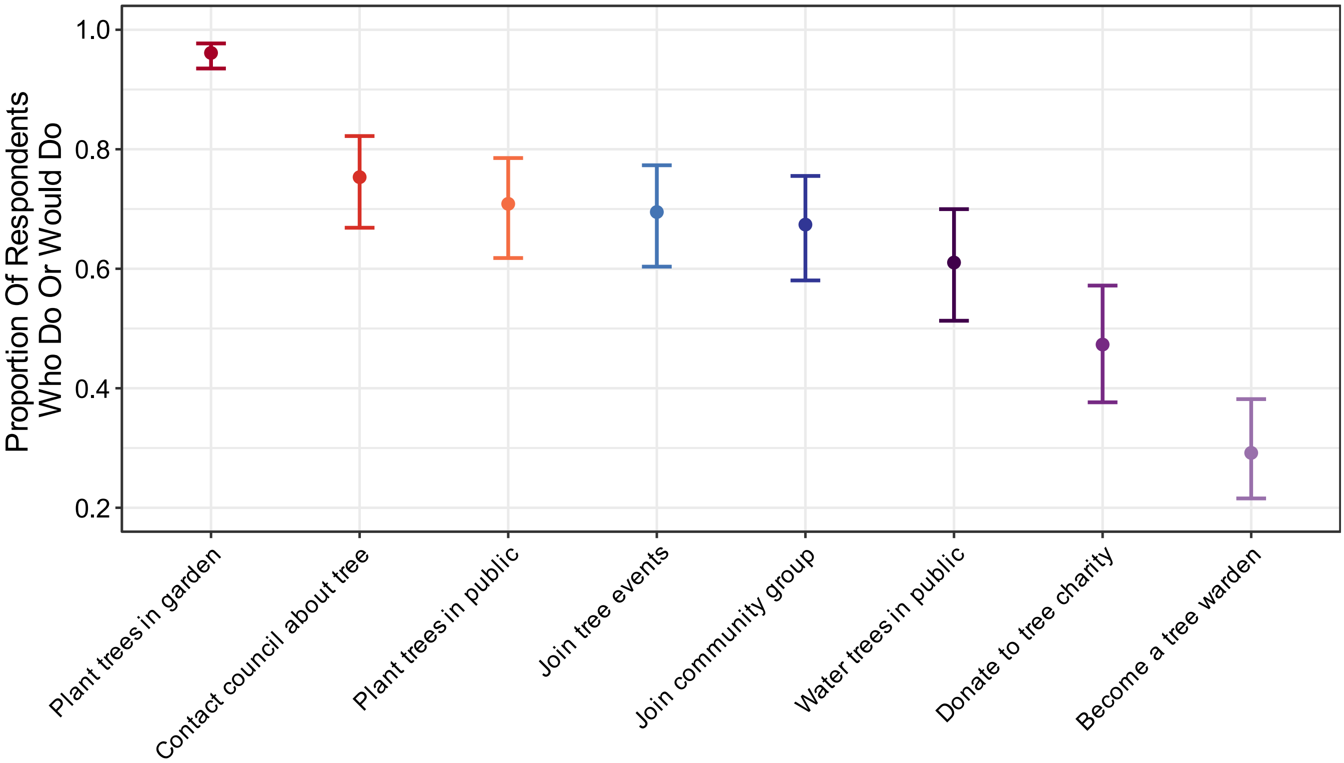


Figure 18. Survey responses about current and potential involvement in a range of tree related activities.

3.1.6 Social and cultural values of local trees

Survey respondents were asked to rate how much they agreed with 19 statements (on a scale from 0 to 100, where 0 is strongly disagree, and 100 is strongly agree) when considering the social and cultural values of their local trees and woods (Figure 19). **Respondents had strong agreement with all the statements**: all statements had a median score of over 50, indicating that people consider trees and woods to be important in many different ways. Nine statements, including **the importance of trees for local wildlife**, **and being part of a landscape which is also home to wildlife**, had median value scores of 100. Trees connecting them to memories of their past and providing places for the community to come together ranked lowest.

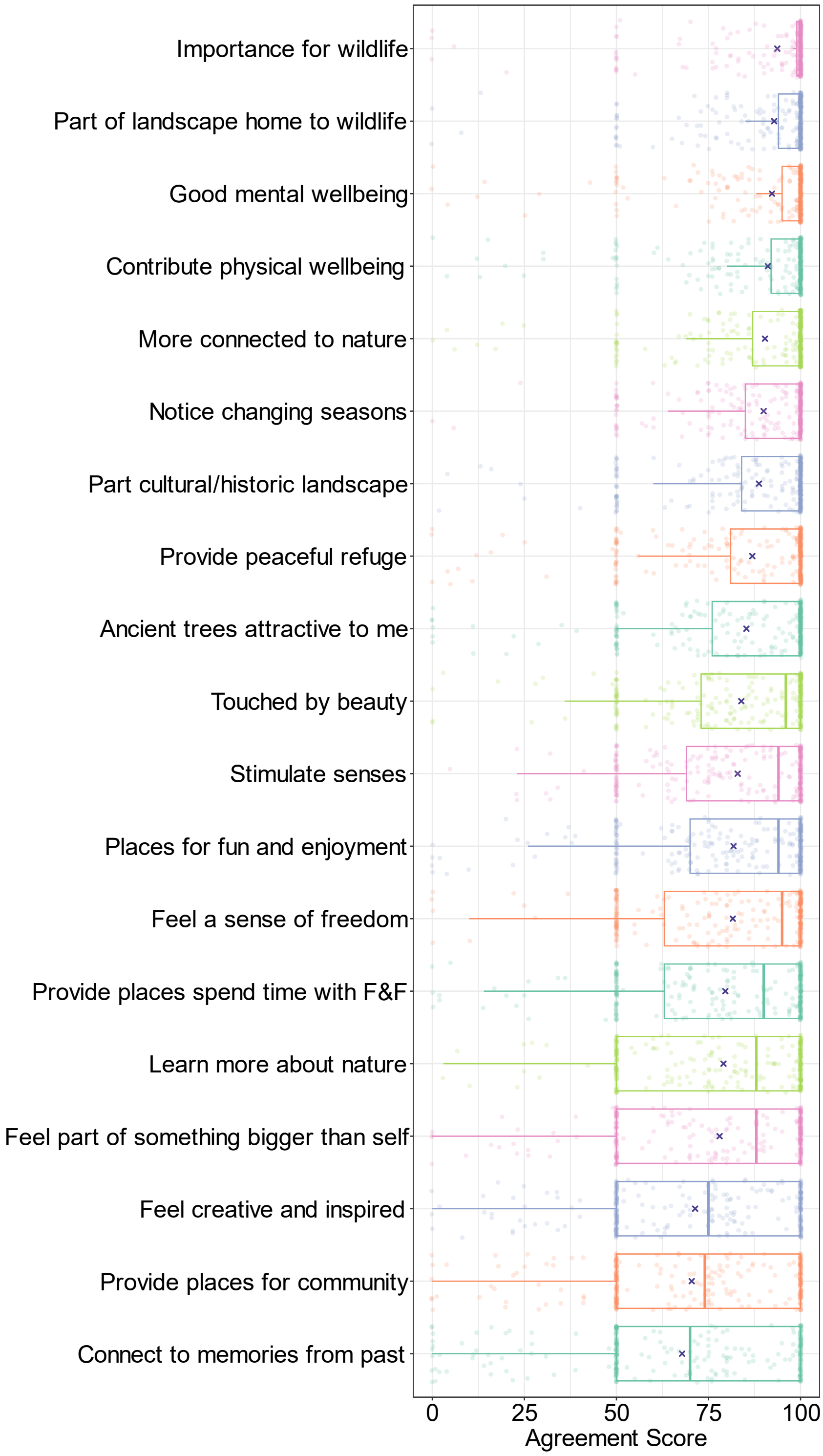


Figure 19. Responses to the 19 statements on the social and cultural values of trees and woods. Circles represent individual agreement scores. Centre lines in the boxes show the median score; the box limits show the 25% and 75% percentiles of the data (50% of the data points lie within this range). The median score for the first nine statements is 100. Crosses show the mean agreement score.

The same statements have been used in an England-wide survey representative of the age, gender, and region of the overall population (O'Brien et al., 2023). The England population study involved undertaking an exploratory factor analysis to investigate relationships between the statements, by finding which of the 19 statements correlated with each other and by looking for underlying factors that explained the correlations. Four factors were identified which explained over 70% of the variance in the statements, and which highlight key dimensions of social and cultural values. These were interpreted as: 1) Nature and landscape; 2) Social space; 3) Reflective and creative; and 4) Wellbeing.

In this i-Tree Eco study we used the same 19 statements and took the opportunity to undertake a confirmatory factor analysis to test the relationships between the statements using the four factors from O'Brien et al. (2023). The 19 statements correlate together into the same four factors despite the population samples being different[6].

The statements outline the important social and cultural values of trees and woods to people and provide a standardised approach for understanding these values that can be used in further studies or in future work to explore change.



[6] Good correlation with composite reliability of 0.8 or above, and statement loadings of 0.7 or higher between this project and the England-wide data.

3.2 Land cover

3.2.1 Canopy cover

The overall **tree canopy cover in Wirral is estimated to be 13.4%**[7]. Table 10 gives the canopy cover for each IMD quintile. In general, areas of Wirral with higher levels of deprivation have lower canopy cover. There is no single agreed target canopy cover for urban areas in the UK: 20% tree canopy cover can be a good aspiration for towns and cities (Doick et al., 2017), the current UK government target is 16.5% of England's total land area (Defra, 2023), and the 3-30-300 rule suggests that there should be 30% canopy cover in urban areas (Konijnendijk van den Bosch, 2021). IMD quintile 5 reaches the 16.5% target, but the other quintiles do not reach any of the suggested canopy cover targets.

Table 10. Canopy cover data calculated from webmap point data for IMD quintiles and the whole study area.

IMD quintile	Canopy Cover ± SE
1	9.1 ± 0.5
2	12.4 ± 0.8
3	16.0 ± 0.8
4	15.8 ± 0.7
5	16.6 ± 1.0
Study area	13.4 ± 0.9

3.2.2 Ground cover

Permeable surfaces dominate the ground cover across the study site, covering 77% of the area, and including bare soil, permeable rock, herbaceous plants and ivy, grass, mulch, and water or wetlands. The remaining 23% consists of buildings, cement, tar, and other impermeable surfaces. Impermeable surfaces increase the

[7] Data from Forest Research's Canopy Cover Webmap: https://www.forestresearch.gov.uk/research/i-tree-eco/uk-urban-canopy-cover/.

potential for surface water flooding by preventing, slowing, or reducing infiltration into the soil. Impermeable surfaces such as tar also contribute to local heating of urban environments. A greater proportion of permeable surfaces is therefore favourable. The presence of trees in both permeable and impermeable surfaces reduces surface water flooding, as discussed on page 65. See Appendix A for details of the ground cover categories used in the survey.

3.2.3 Land use

Figure 20 shows the distribution of land uses in each IMD quintile. Quintile 1, the most deprived area, has the largest proportion of residential, transport, and industrial land uses. Quintile 2 has the highest proportion of parks or greenspace. Quintile 4 has the highest proportion of agricultural land use.

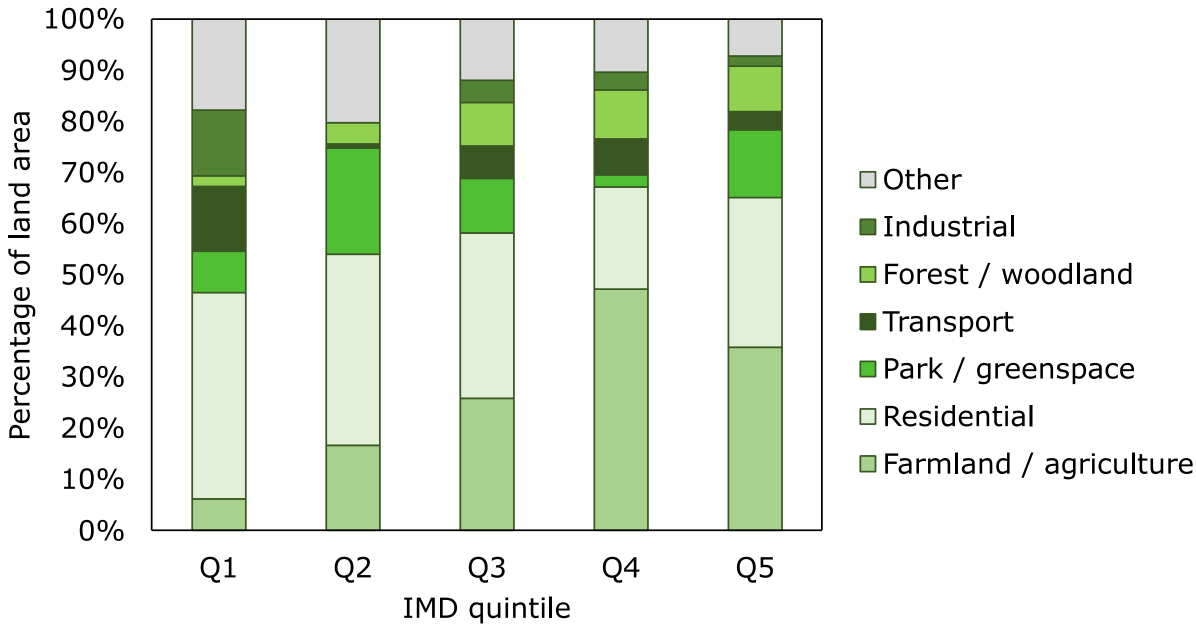


Figure 20. Land use in each IMD quintile, extrapolated from survey data. "Other" includes cemetery, golf course, vacant, water/wetland, institutional, and land uses recorded as other.

Figure 21 shows the percentage of surveyed trees in each land use, and the percentage of the total study area used for each land use. **Farmland represents**

30% of the total study area but contains less than 3% of the surveyed trees. Increasing tree canopy cover on agricultural land by working with landowners to plant new trees could help Wirral achieve its target of doubling canopy cover by 2030. Forest and woodland represents less than 10% of the study area but contains over 40% of the surveyed trees. A detailed spatial evaluation of land use and tree cover within Wirral would enable mapping of tree planting opportunities.

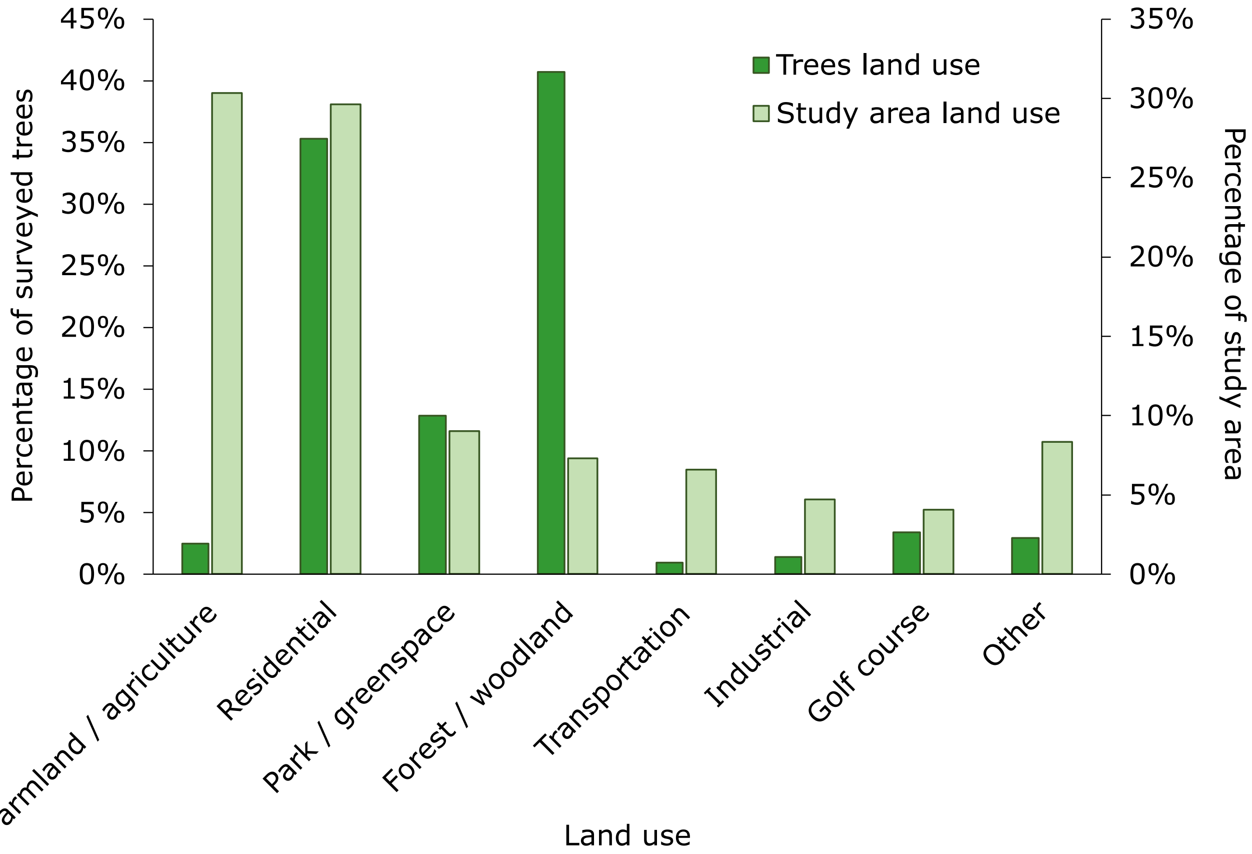


Figure 21. Land uses where surveyed trees were located, the percentage of trees found in each land use, and the percentage presence of land uses in the whole study area.

Survey respondents were asked where they felt trees make the most positive contribution to their neighbourhood and to Wirral, rating **urban woodlands and**

public parks/recreational areas as the areas being rated the highest (Figure 22).

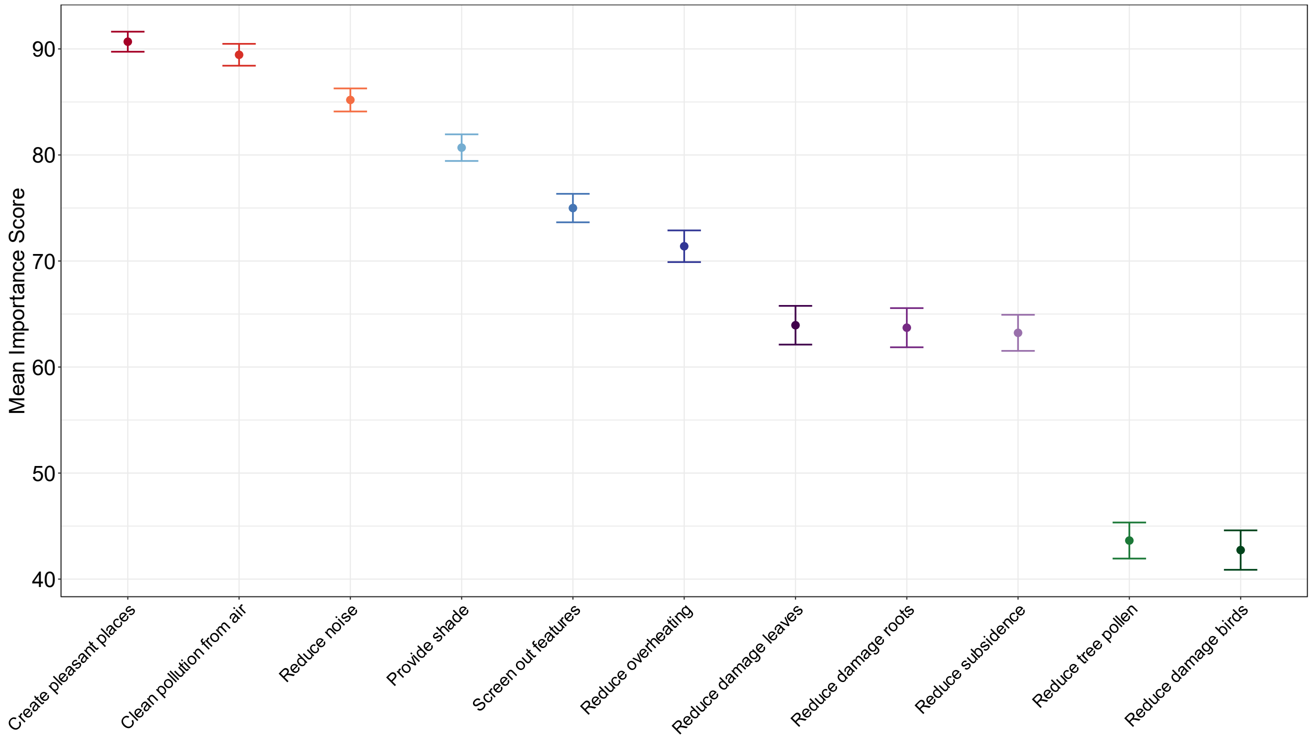


Figure 22. Survey respondent's average (mean) rating of the contribution trees make in different areas.

3.3 Urban Forest Structure

3.3.1 Species composition

A total of **74 tree species** were recorded across the study area (for a full list of tree species, see Appendix B). The three most common species were ***Acer pseudoplatanus*** (11.5%), ***Quercus robur*** (8.6%), and ***Betula pendula*** (6.1%). Figure 23 shows the 10 most common species, which account for 57% of the tree population.

Many survey respondents said they would like to see **more oak trees** in their local area or neighbourhood (~20%). After oak trees, rowan, cherry, birch, and fruit trees were the species that people would like to see more of in their local area. Just over 20% of people said they would not like to see more conifer trees in their local area (note - this category included people who cited conifer or leylandii). Sycamore was cited by 10% of people as a tree they would not like to see more of in their local area, however; 2% of participants said they would like to see more sycamore planted.

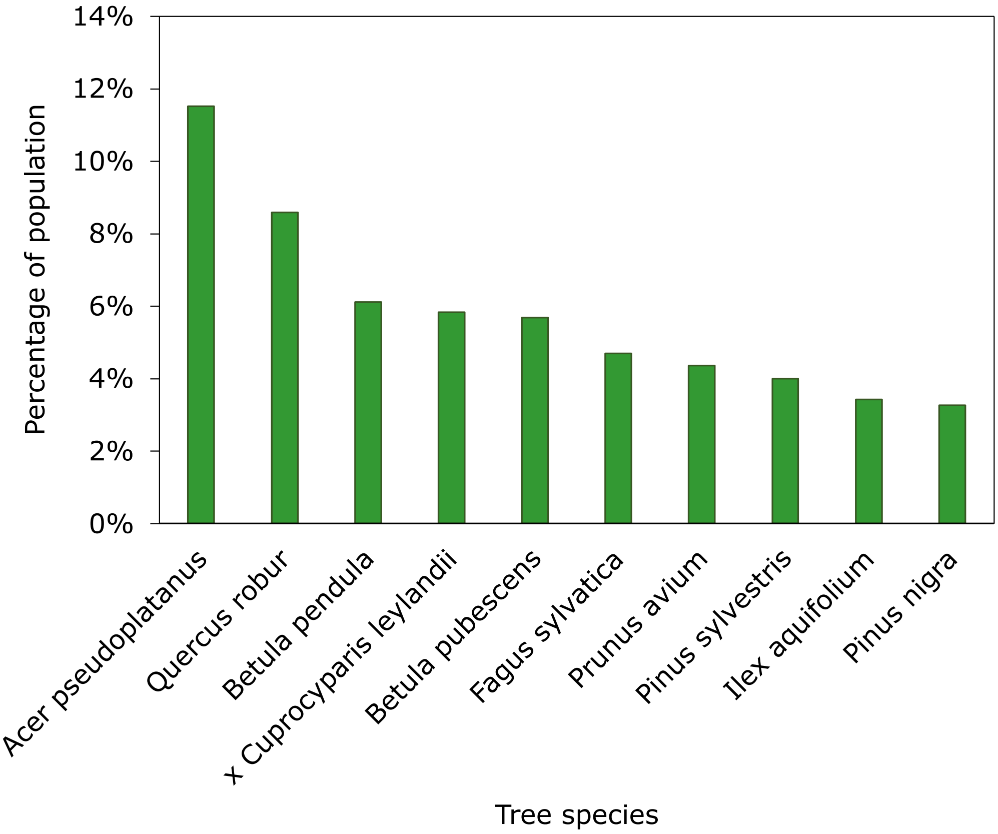


Figure 23. Ten most common species in Wirral's tree population.

Species composition varied between IMD quintiles. The most common species in quintiles 1, 3, and 4 is *Acer pseudoplatanus*. The most common species in quintile 2 is *Quercus robur*, and the most common species in quintile 5 (least deprived) is *Prunus avium*. Figure 24 shows a graphical representation of the species composition in each IMD quintile. Colours represent the same species or genus across the quintiles.

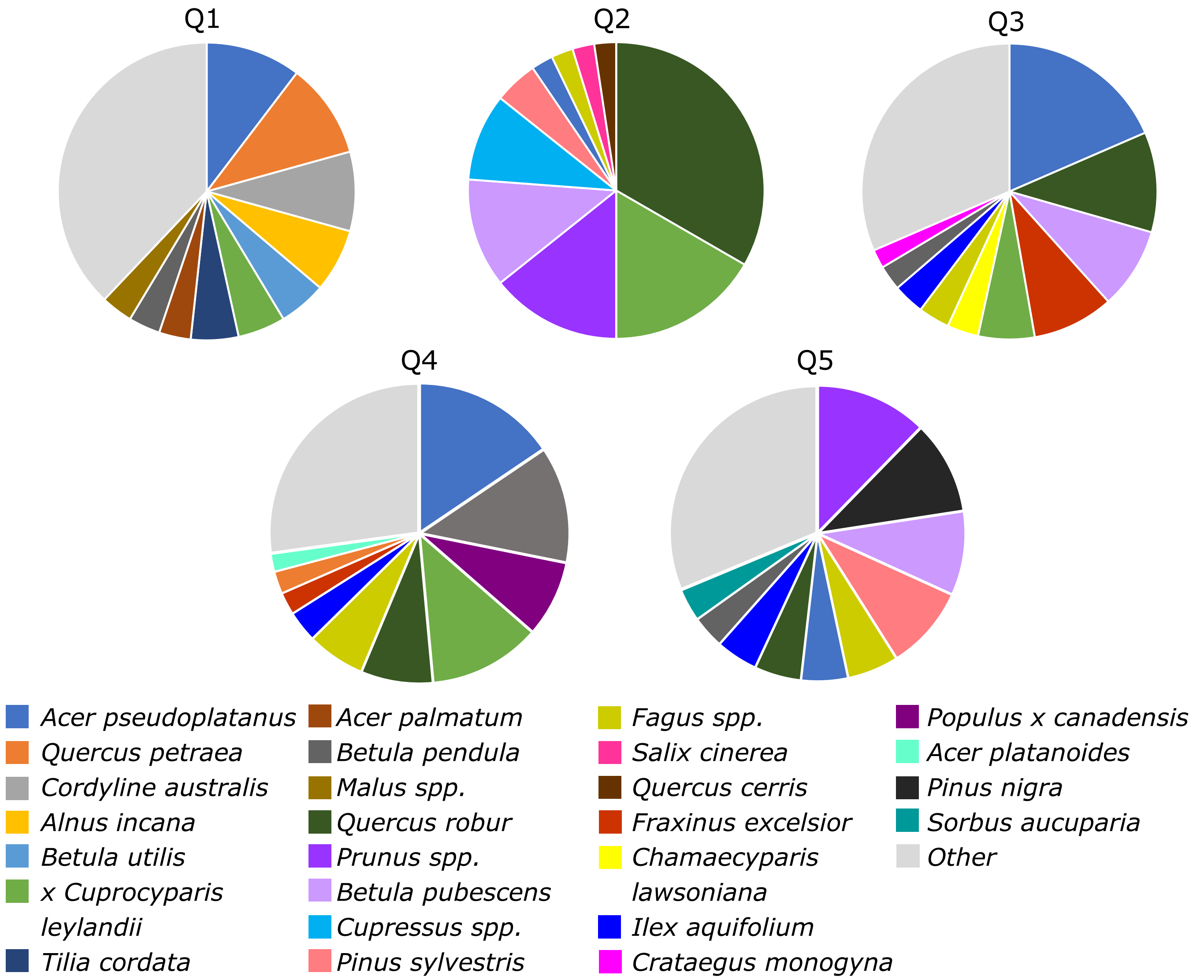
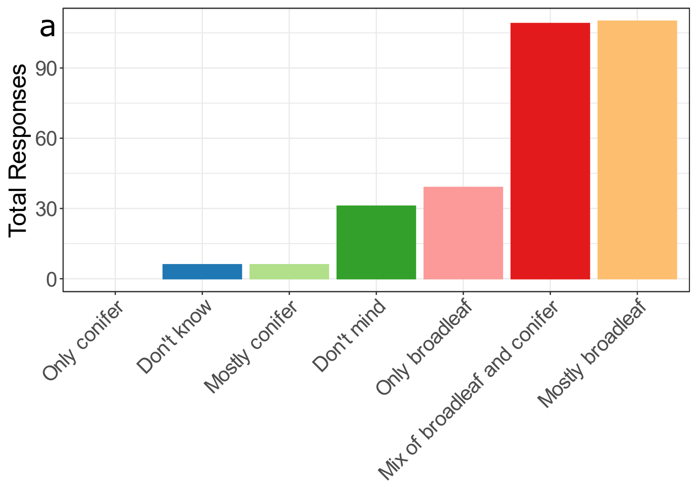


Figure 24. Graphical representation of species composition of IMD quintiles. Colours represent the same species or genus across the quintiles.

Survey respondents were asked three questions about the types of trees they would like to see in their neighbourhood/local area. Whilst most people seemed to prefer broadleaf trees (Figure 25a) there was also support for seeing a mixture of broadleaf and conifers, a mixture of small and large trees (Figure 25b) and a mixture of trees which changed throughout the seasons and evergreens (Figure 26).



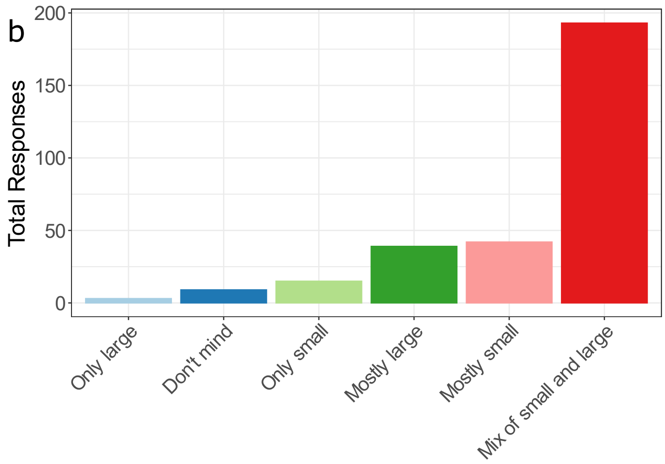


Figure 25. Survey respondents' preferences regarding a) conifer and broadleaved trees and b) size of trees.

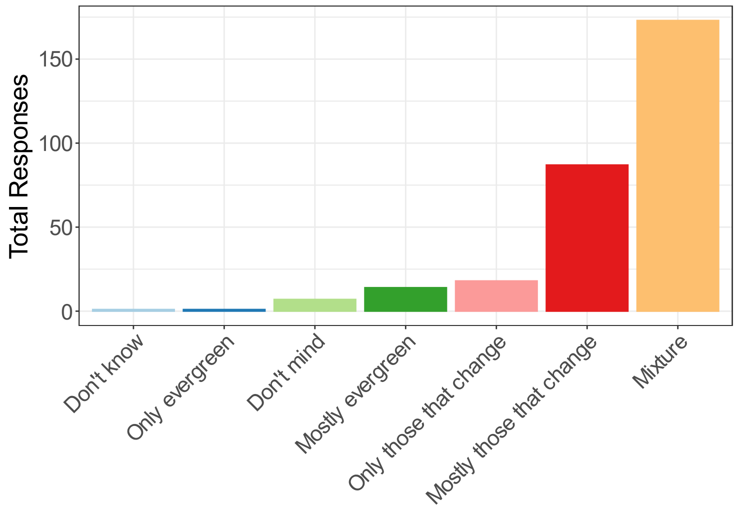


Figure 26. Survey respondent's preferences regarding seasonality of trees.

3.3.2 Species composition by origin

An estimated **54% of Wirral's trees are native to the UK**. A further 18% are naturalised (such as *Acer pseudoplatanus*, *Populus alba*), and 20% are non-native. Native species can be an important source of food and habitat for invertebrates and other wildlife. Non-natives also have the potential to provide for local wildlife but may not be suitable for specialist feeders or those that take time to adapt. As such, where wildlife provision is an important selection factor for future tree planting, further information should be sought on suitability. For information on food and habitat provided by Wirral's trees, see page 77.

Survey respondents were asked questions on the variety of trees they would like to see planted in their area and also whether these trees should be native or non-native. They were also asked to list if there were particular types of trees they would like to see planted in their local area. Just over half of participants (53%) said they would like these trees to be mostly native but a quarter said they would like to see a mix of native and non-native species planted in their local neighbourhood (Figure 27).

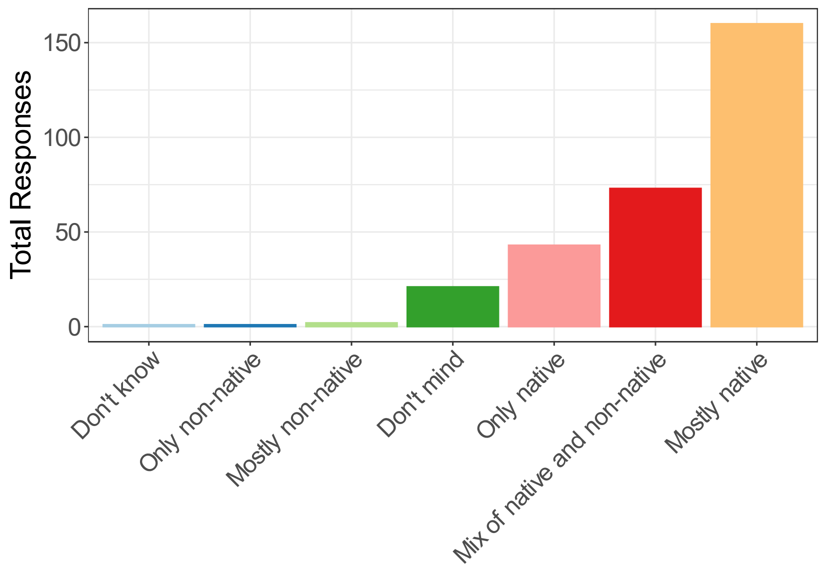


Figure 27. Survey respondent's preferences regarding origin of trees.

Native and non-native species

Non-native species can make an important contribution to the urban forest. Forest Research's Climate Matching Tool suggests that by 2070 Wirral will have a climate similar to the current climate of south and south-west England and the north coast of France. Native species that currently thrive in Wirral's urban forest may no longer be suitable in the future climate: they may not tolerate the additional environmental stresses and they may be susceptible to pests and diseases whose range and behaviour are expected to change with climate change.

Native and non-native species continued

The Right Trees for a Changing Climate database provides information on tolerances of tree species to environmental conditions, and their geographic origin. Along with species guidance from TDAG, it can help to inform species selection for sustainable urban planting.

Non-native species may be essential components of urban forests to ensure delivery of ecosystem services (Sjöman et al., 2016). While native species are more likely to support larger numbers of species, there is emerging evidence to indicate that non-native trees also support biodiversity in urban areas (Schlaepfer et al., 2017).

Respondents to the survey expressed a preference for native species over non-native species. Creating opportunities for engagement and education about the potential importance and resilience of non-native species in urban areas could promote public support for the planting of exotic species.

3.3.3 Diversity

Increased tree species diversity (the number of different tree species present and their population sizes) can offer a higher level of resilience to pests and diseases, as there is less potential for large numbers of trees to be affected by an outbreak. There are different approaches to assessing whether an urban forest has a suitable level of species diversity. Santamour (1990) recommended that no species should exceed 10% of the total urban tree population, no genus 20%, and no family 30%. Considering this approach, the following was observed across the study area:

- ***Acer pseudoplatanus* represents 12% of the total population**, exceeding Santamour's species guideline of 10%
- No genus exceeds 20% of the population
- No family exceeds 30% of the population

There have since been suggestions of a 5-10-15 rule (Watson, 2017). Considering this approach:

- **Six species exceed the 5% guideline** (*Acer pseudoplatanus, Quercus robur, Betula pendula, x Cuprocyparis leylandii, Betula pubescens, Fagus sylvatica*)
- **Three genera exceed the 10% guideline** (*Acer, Quercus, Betula*)
- **Three families exceed the 15% guideline** (*Fagaceae, Betulaceae, Rosaceae*)

The diversity of populations can be calculated using the Shannon-Wiener index, which measures the number of different species and their dominance within a population. A further metric, evenness, can be calculated from the diversity index and the number of species in each quintile. The higher the diversity, the closer the evenness is to 1. See Appendix A for details of the calculation. Table 11 gives the Shannon-Wiener diversity indices and evenness scores for species of tree in each IMD quintile. There is little to separate the quintiles, except that quintile 1 has the highest evenness score. Tree species diversity is typically high in residential land use. Quintile 1 has the highest proportion of residential land use.

Table 11. Shannon-Wiener diversity index scores for tree species found in each IMD quintile.

IMD quintile	Shannon-Wiener Diversity Index Score	Number of species	Evenness
1	3.1	29	0.93
2	2.0	11	0.83
3	3.1	43	0.83
4	3.2	47	0.82
5	3.2	45	0.84

3.3.4 Size class distribution

Understanding the distribution of size classes within an urban forest population is important for two primary reasons. One is that it can be used as a proxy for age, and this can help offer insights into the sustainability of an urban forest, and whether there is a need to increase tree planting efforts to address potential shortfalls in tree numbers in the future. Secondly, larger trees deliver a greater amount of ecosystem services than smaller trees (Sunderland et al., 2012; Hand et al. 2019a, 2019b). It is therefore important that, wherever practically possible, large mature trees should be retained and large stature trees[8] should be incorporated into new planting. It is also important that trees are supported through to maturity to maximise the ecosystem service delivery of the urban forest.

Richards (1983) suggested the ideal street tree distribution to ensure a healthy stock is:

- 40% of trees with a DBH <20 cm,
- 30% of trees with DBH from 20 to 40 cm,
- 20% of trees with DBH from 40 to 60 cm and
- 10% of trees with DBH >60 cm.

Figure 28 shows the size class distribution of measured trees in each IMD quintile and in the overall study area. Every quintile has more than 40% of trees with a DBH < 20 cm. Apart from quintile 2 (28.6%), every quintile has more than 30% of trees with a DBH between 20 and 40 cm. None of the quintiles reach the suggested proportions for the two larger size classes, indicating that **the overall population is smaller (or younger) than ideal**.

[8] Large stature tree species are defined as those for which a healthy, isolated 20-year-old specimen growing in good soil conditions is typically over 12 m high (Stokes et al., 2005).

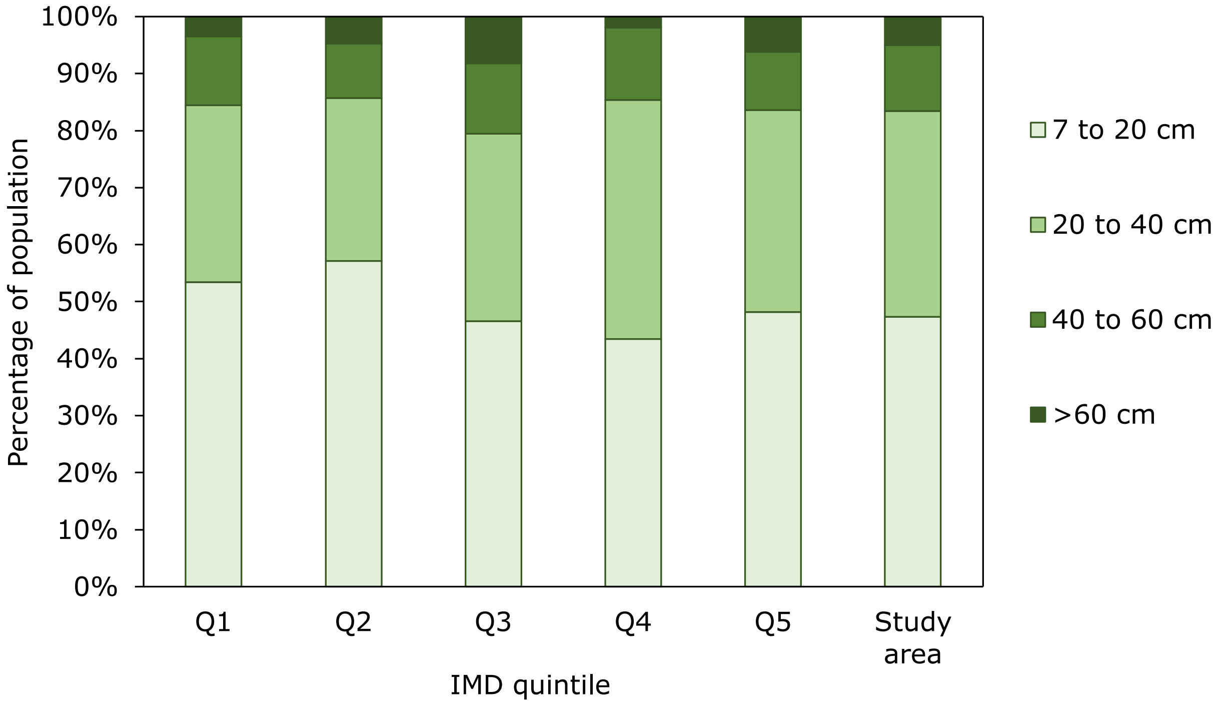


Figure 28. DBH classes of measured trees in each IMD quintile and the study area.

Respondents to the survey were asked about their preferences for small and large trees, and the size of trees they could see from their homes. Sixty-four percent of respondents said they would like to see a mix of small and large species (Figure 25b). Respondents living in the most deprived areas of Wirral were more likely to say that there were too few large trees in their street, compared to respondents from the least deprived areas (Figure 13).

3.3.5 Tree condition

Trees in poor condition provide lower ecosystem service delivery and can represent a health and safety concern, and therefore a management and financial burden on a local authority. Poor condition slows or prevents growth and may result in defoliation or crown dieback, reducing the tree’s capacity for carbon sequestration, rainwater interception, and air pollution removal (Hand et al., 2019a). A tree in poor condition usually has a lower public amenity value and higher susceptibility to attacks by pests and diseases. However, where their retention is appropriate, dead trees and trees with veteran characteristics such as cavities and deadwood are important for providing habitat for birds, bats, lichens, fungi, and invertebrates.

Tree condition is an important metric for giving an estimate of the current state of Wirral’s tree population. Condition is assessed by assigning scores relating to loss of leaves and the dieback of branches within the tree’s crown. The results of this assessment could be a useful indicator of the possible presence of pests or diseases, unsuitable or poor management, unfavourable site conditions, or may warrant further investigation to understand whether there are any attributable causal factors.

Of Wirral’s total tree population, 8% were in excellent condition, 44% in good condition, 30% in fair condition, 9% in poor condition, 3% in critical condition, 4% were dying, and 2% were dead. Figure 29 shows the ten most common species across the whole study area, and the proportion of each species classified into each condition rating. Only five of the ten most common species have any trees in excellent condition. The species with the overall best condition is *Acer pseudoplatanus*, with 64.2% of the population rated as excellent or good. The species with the overall worst condition is *Pinus sylvestris*, with just 60.2% of the population rated as good or fair, and none rated as excellent. A detailed survey of *P. sylvestris* across Wirral could reveal more information about the cause of their relatively poor condition.

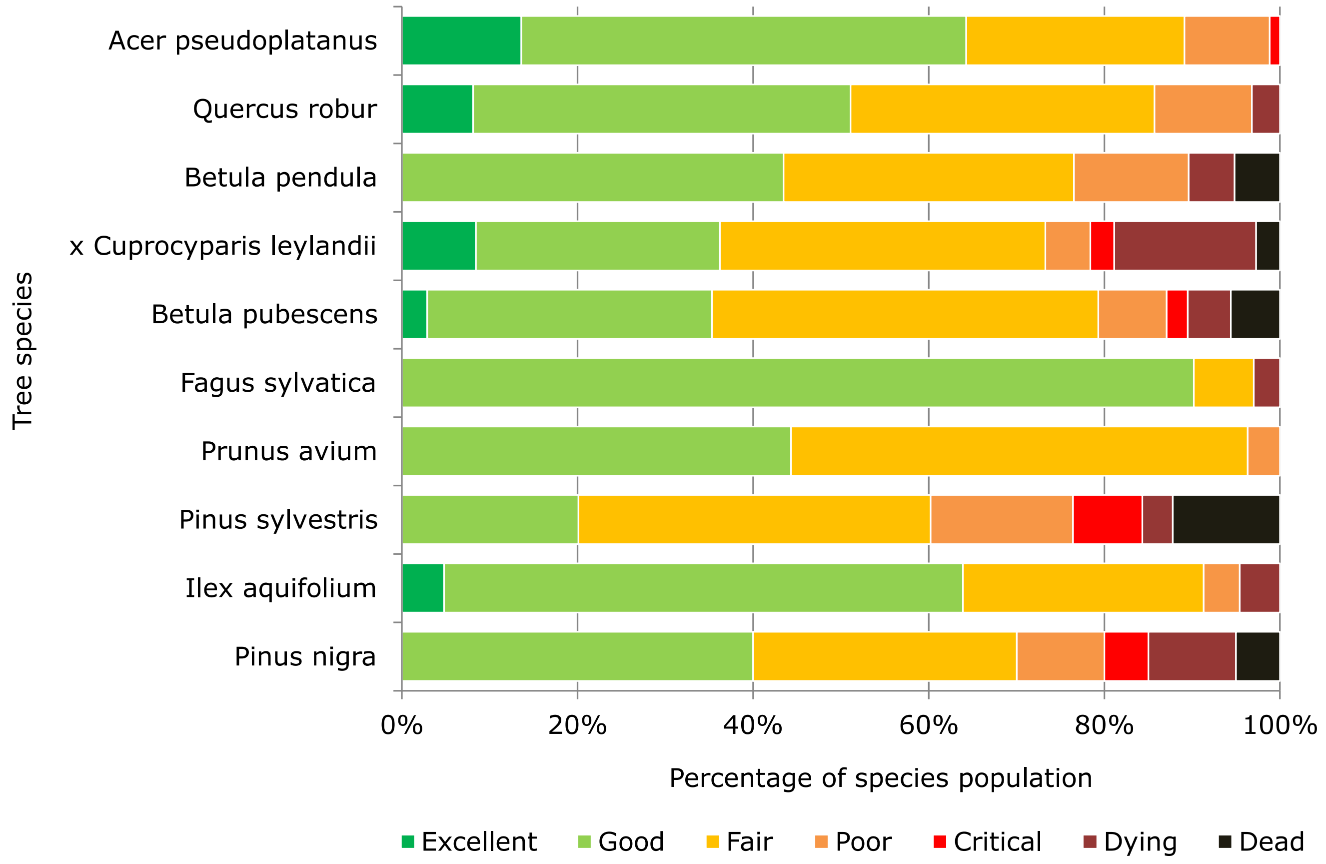


Figure 29. Percentages of the ten most common trees in the study area classified according to their overall condition.

Figure 30 shows the condition rating for trees in each of the five IMD quintiles. There is little difference in condition between the quintiles, but it is notable that quintile 2 has the largest proportion of trees in poor, critical, dying, and dead conditions. The tree population in quintile 2 is dominated by *Quercus robur* (33%), *x Cuprocyparis leylandii* (17%), *Prunus spp.* (14%), *and Betula pubescens* (12%).

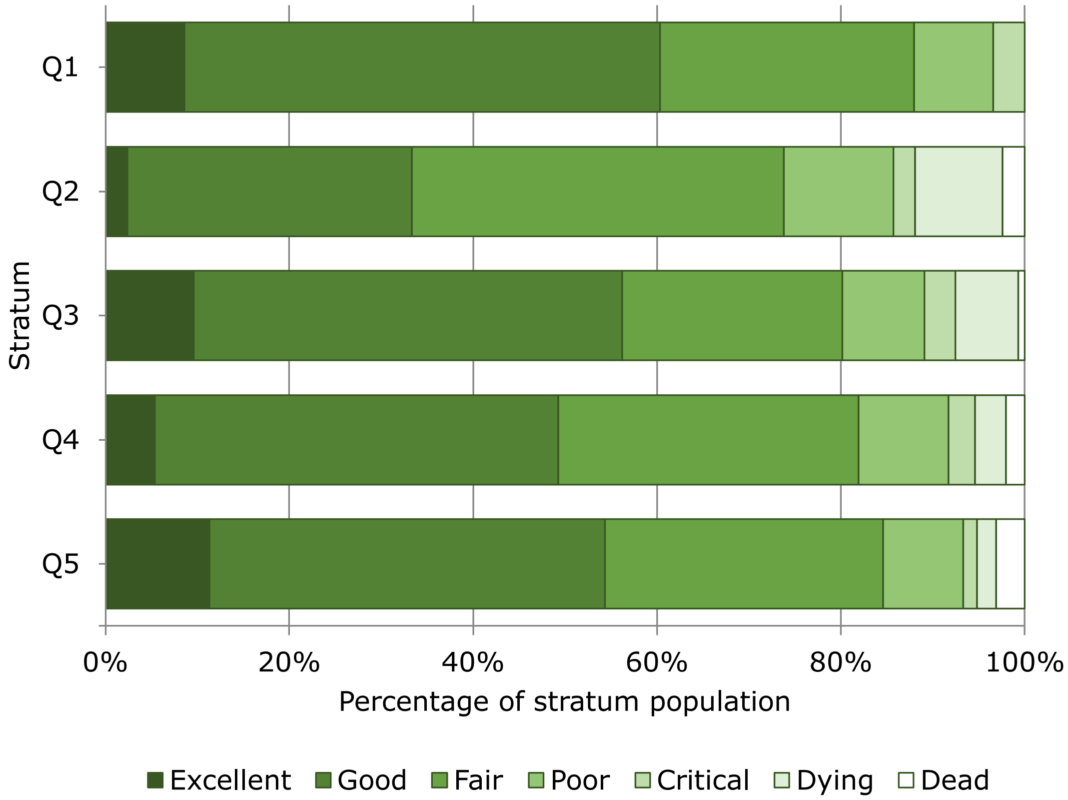


Figure 30. Percentage of strata tree populations classified according to their overall condition.

Survey respondents were more likely to think that the trees in their street were healthy compared to trees across Wirral (Figure 31). The perception of tree health was not associated with area deprivation, gender or age.

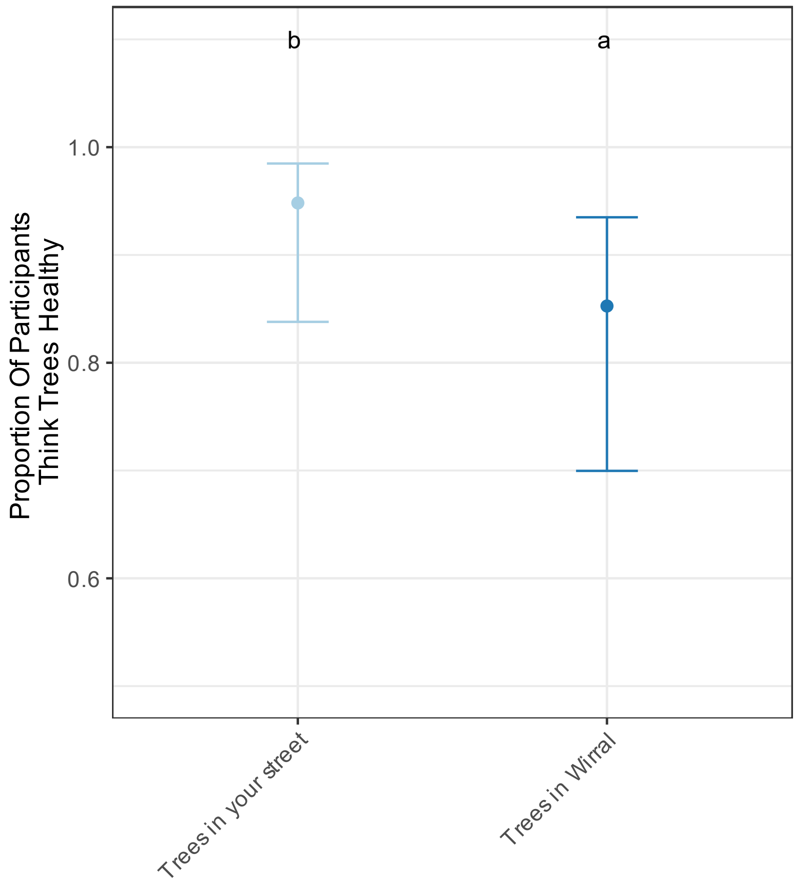


Figure 31. Survey respondent's perception of tree health in their street and in Wirral.

3.3.6 Leaf area and importance value

Leaf area is the total surface area of leaves found within a tree's crown. Leaves are an important component in provision of ecosystem services; larger leaf area often results in greater benefit provision.

Importance value is a measure of how dominant a species is in its environment. It is a standard tool used in forest inventories. A high importance value indicates that a species is well represented because of a large number of individuals, large-sized individuals, or large leaf area contribution. i-Tree Eco calculates importance value as the sum of leaf area expressed as a percentage of the total leaf area, and the number of individuals of a species expressed as a percentage of the total number of trees. Trees with dense canopies and trees with large leaves tend to rank highly. A full list of importance values for all species in the study is given in Appendix B. Figure 32 gives the population, leaf area, and importance value for the ten most dominant species.

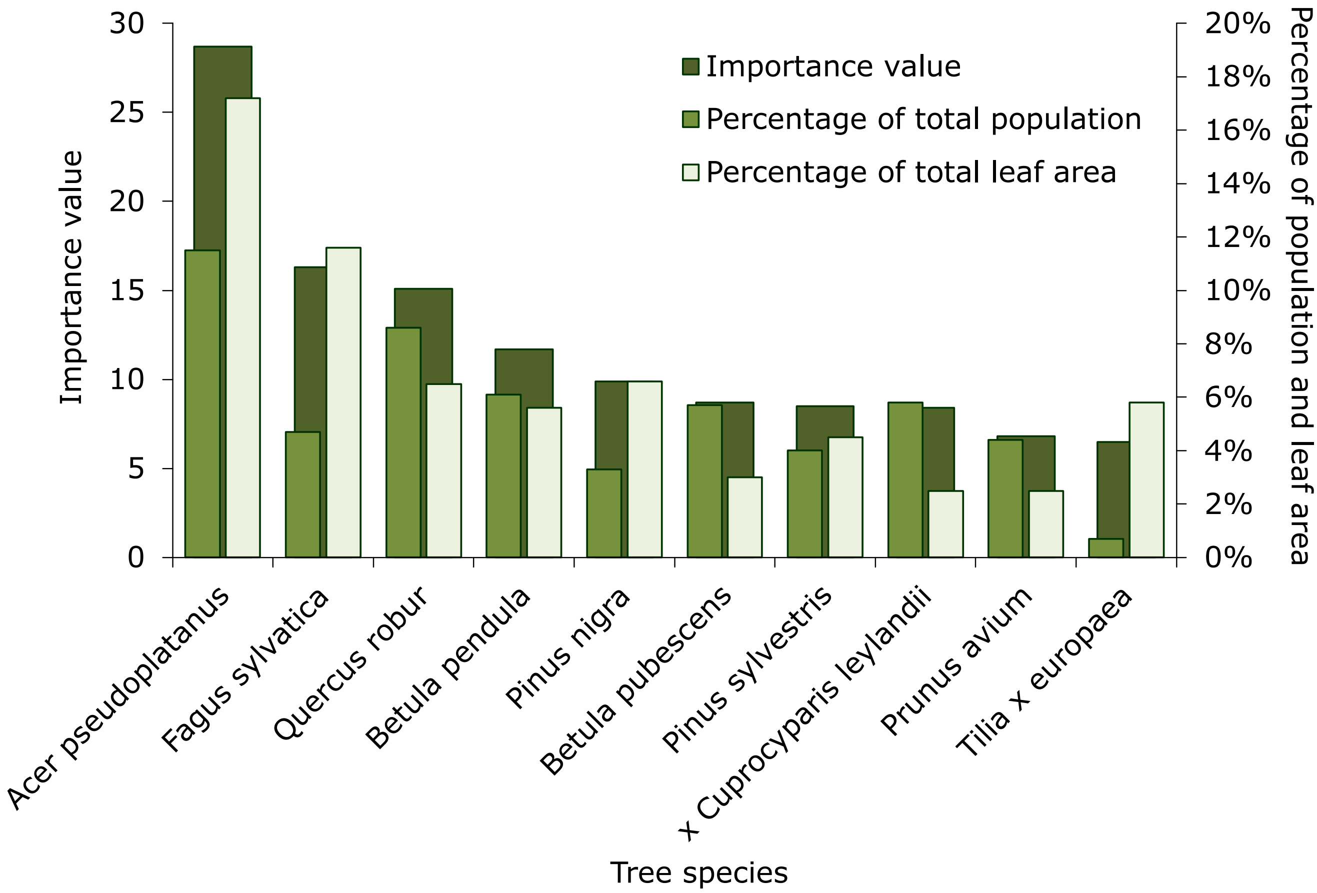


Figure 32. Importance value of the ten most dominant species in Wirral's tree population.

Acer pseudoplatanus represents 12% of the tree population, and 17% of the total leaf area, owing to its large size and dense foliage. It ranks highest in importance value, followed by *Fagus sylvatica* and *Quercus robur*. Note that *F. sylvatica* represents less than 5% of the tree population, but its large, dense crowns make it an important species for ecosystem service delivery.

i-Tree Eco importance value

The science that underpins i-Tree Eco reveal a direct relationship between leaf area and the provision of ecosystem services. Thus, in i-Tree Eco, importance value is the sum of leaf area and population size. If the most common trees have larger leaves or large tree canopies, then they tend to rank higher in importance.

The term importance value can lead to assumptions that these are the tree species that should form the core of any future planting strategy. This relationship is also termed the dominance value, showing which species are currently delivering the most benefits based in their population and leaf area.

Maintaining a healthy population of these trees is important for the current provision of ecosystem services to society. Therefore, where large stature trees, such *Acer pseudoplatanus* and *Fagus sylvatica* are currently found, it will be important to make provision to retain these trees to maturity.

3.4 Ecosystem Services

3.4.1 Avoided surface water runoff

The issue

In urban areas a high proportion of land is covered by impermeable surfaces. This increases the risk of surface water flooding, resulting in damage and disruption, high water treatment charges, and sewage releases into watercourses.

How trees can help

The canopies of trees intercept rainfall. Water evaporates from the leaf surfaces, which reduces the total amount that reaches the ground. Water falls from the leaf surfaces at a slower rate than rainfall, smoothing out the peak of potential surface flooding. Transpiration is the process of water being taken up from the soil by a tree’s roots, being transported to the canopy, and being released into the atmosphere through stomata. The roots of trees create voids and channels in soil and encourage water infiltration. These functions are combined into the hydrological model within i-Tree Eco (Hirabayashi, 2013), which calculates the overall amount of surface water runoff that is avoided due to the presence of trees and other vegetation.

Wirral's trees

Figure 33 shows the annual avoided runoff and the associated value for ten species that contribute most to avoided runoff in Wirral. The value is calculated using the United Utilities foul drainage volumetric charge of £1.221 per m^3 (United Utilities, 2022). ***Acer pseudoplatanus*** alone prevents 43,000 m^3 of surface runoff per year, worth an estimated £53,000. *A. pseudoplatanus* represents 12% of the tree population, and 17% of the total leaf area (see Figure 32). The **total volume of avoided runoff each year is more than 250,000 m^3**, equivalent to 100 Olympic swimming pools, with an annual value exceeding **£300,000**.

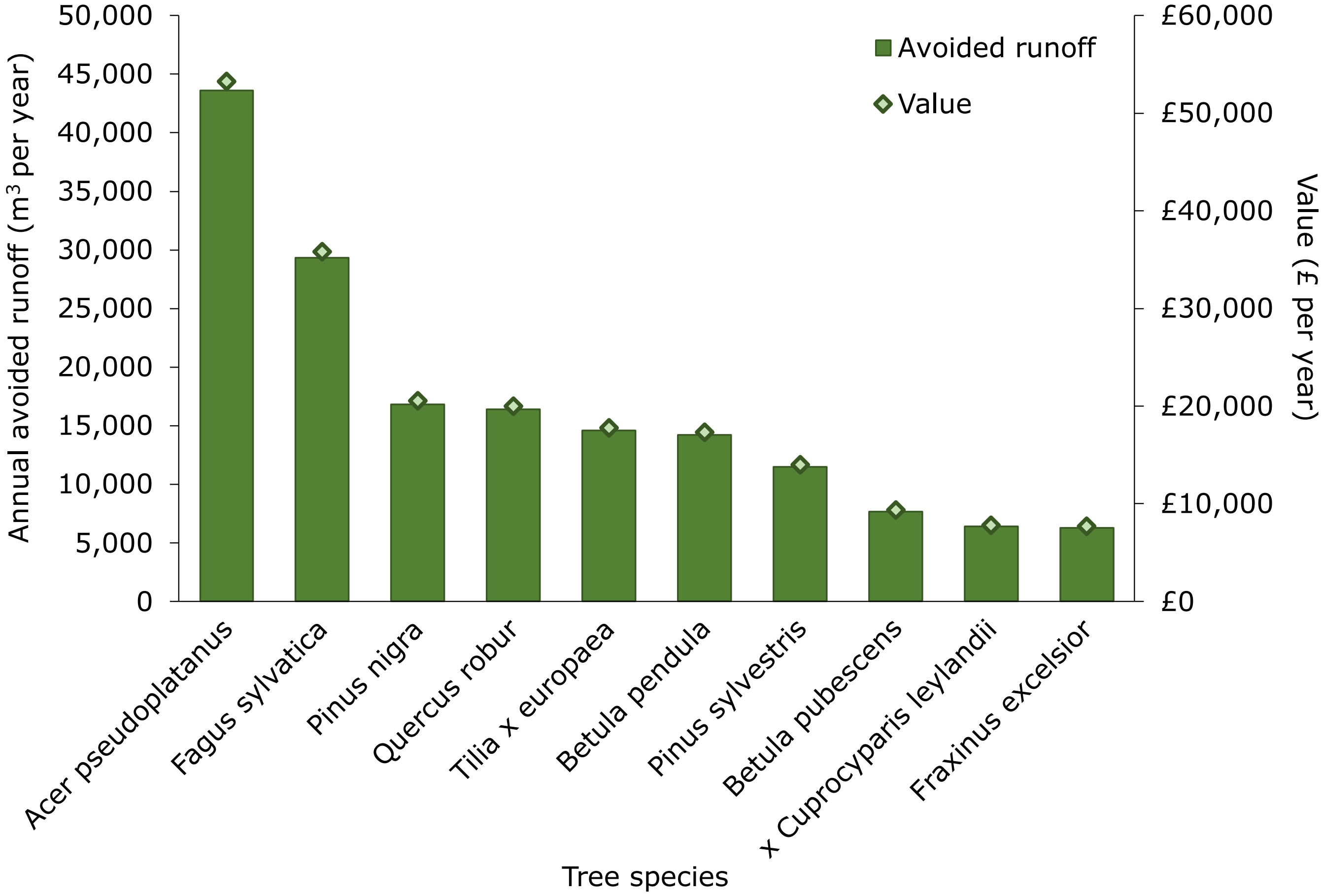


Figure 33. Annual avoided runoff and value for the ten species that contribute most to avoided runoff in Wirral.

The most deprived areas of Wirral have the lowest canopy cover, and the lowest total leaf area, leading to the lowest amount of annual avoided runoff (Figure 34). They also have more built-up area than other areas of Wirral, which exacerbates the problem of surface water flooding.

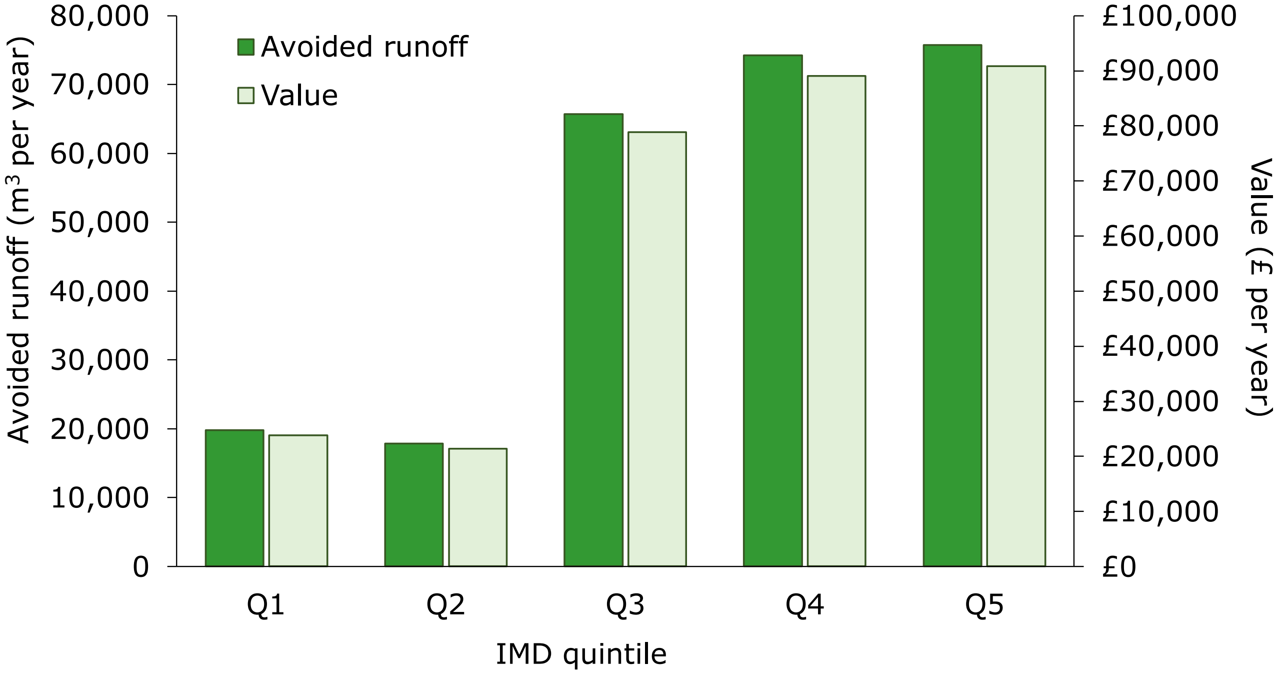


Figure 34. Annual avoided runoff and associated value for each IMD quintile in Wirral.

Reducing flooding in Wirral

Climate change in the UK is expected to lead to increasingly rainy winters, and more frequent intense summer rainfall events (Met Office, 2022). These factors increase the risk of flooding which in urban areas is further exacerbated by a higher proportion of impermeable surfaces such as roads and buildings. The resulting surface water run-off can quickly overwhelm drainage systems and lead to flooding.

In a natural environment, rain which falls onto vegetation is delayed in reaching the soil. Rainwater which reaches the surface infiltrates the soil. The rate at which this happens depends on the type of precipitation and the soil structure, but tree roots can promote infiltration. Once in the soil, water may be drawn up again by plant roots and returned to the atmosphere by transpiration, reducing the chance of saturation.

Reducing flooding in Wirral continued

In a built-up environment interception and infiltration are limited by the presence of buildings, roads, and other hard surfaces, increasing the likelihood of surface flooding. Urban trees intercept rainwater and reduce the rate at which water reaches the ground, and promote soil infiltration, easing pressure on drainage infrastructure. The more deprived areas of Wirral have more built-up land and also have lower canopy cover, making them potentially vulnerable to surface flooding.

Trees can be incorporated into Sustainable Urban Drainage Systems (SUDS). Urban trees frequently suffer drought stress; tree planting as part of a SUDS scheme can take advantage of the supply of water created by the semi-natural catchment and storage features.

In rural areas, there is an important role for trees in slowing down the flow of water across a floodplain and enhancing infiltration, smoothing out the flood pulse and limiting damage and disruption.

3.4.2 Air pollution removal

The issue

Air pollution poses a serious threat to human health (WHO, 2022). Table 12 summarises the health effects and sources of air pollutants. Exposure to air pollution increases the risk of stroke, heart disease, lung cancer, and respiratory diseases such as asthma. There are also links to diabetes, dementia, mental health, and birth outcomes. Long-term exposure to air pollution was linked to a greater risk of hospitalisation because of severe symptoms of COVID-19 (Walton et al., 2021).

Table 12. Air pollutants and their health effects.

Pollutant	Health Effects	Source
Nitrogen dioxide (NO_2)	Shortness of breath, chest pains	Fossil fuel combustion, predominantly cars (44%) and power stations (21%)
Ozone (O_3)	Irritation to respiratory tract, particularly for asthma sufferers	Gas-phase reactions in the presence of sunlight
Sulphur dioxide (SO_2)	Impairs lung function, forms acid rain that acidifies freshwater and damages vegetation	Fossil fuel combustion; predominantly burning coal (50%)
Carbon monoxide (CO)	Long term exposure is life threatening due to its affinity with haemoglobin	Carbon combustion under low oxygen conditions (e.g. in petrol cars)
Particulate matter ($PM_{2.5}$ and PM_{10}*)	Carcinogenic, responsible for tens of thousands of premature deaths each year[9]	Various sources: cars (20%) and residential properties (20%) are major contributors

How trees can help

Urban trees cannot overcome the sources of pollution, but they can reduce people's exposure in three ways. The first is dispersion: trees can act as roadside barriers that decrease the concentration of pollutants downstream of the source by disrupting airflow and increasing turbulence. The second is deposition: trees absorb gases through leaf stomata, and absorb gases and particles onto their surfaces (Defra, 2018). The third is local cooling: trees and greenspaces reduce the urban heat island effect, slowing the production of some secondary pollutants such as ozone (O_3) (Jacob and Winner, 2009). Deposition is the focus of air pollution removal by trees in the i-Tree Eco model.

[9] Source: https://www.air-quality.org.uk/18.php.

Wirral's trees

Figure 35 shows the annual removal of air pollutants, and the associated value for NO_2, SO_2, $PM_{2.5}$ and PM_{10}*. $PM_{2.5}$ is particulate matter smaller than 2.5 microns wide; PM_{10}* is particulate matter larger than 2.5 microns and smaller than 10 microns wide. Values have been calculated using the 2022 UK damage costs[10] (see Table 7). The **total annual value of air pollution removal by Wirral's trees is £1.1 million per year**. Figure 36 shows leaf area and pollution removal for the ten species that remove the most pollution in Wirral. Only deposition is taken into account in the i-Tree Eco model, and there is a strong link between leaf area and pollution removal, with ***Acer pseudoplatanus*** once again providing the greatest benefit.

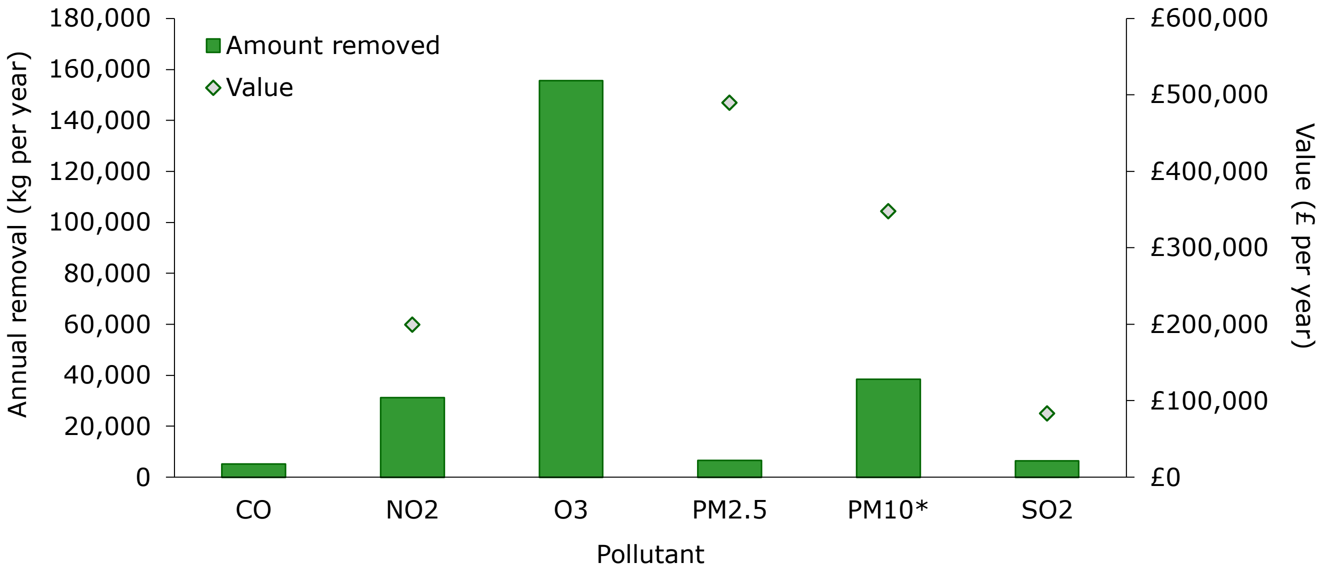


Figure 35. Annual removal of air pollutants by Wirral's trees, and the associated value.

[10] There are no UK damage cost calculations for CO or O_3 so they have not been valued in this report.

It is interesting to note that *Pinus nigra* is in the top ten species for air pollution. This species represents 3% of the total tree population and contributes 7% of the pollution removal. Evergreen conifers retain their needle-like leaves all year round, leading to year-round air-cleaning benefits. This finely-divided surface has shown to be particularly effective at intercepting air pollution.

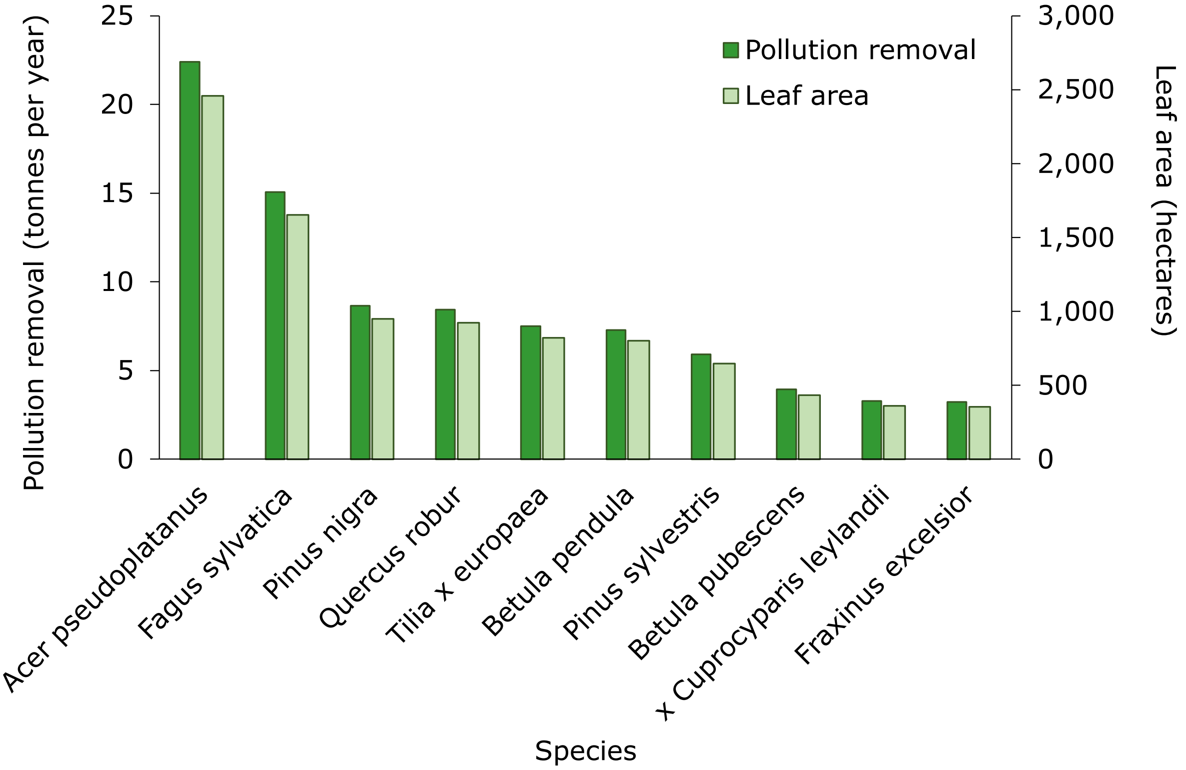


Figure 36. Annual pollution removal and leaf area for the ten species that remove the most air pollution per year in Wirral.

The rate of deposition of pollutants onto the surfaces of trees, and through leaf stomata, depends on the concentration of the pollutant, the type of vegetation, and the density of the vegetation. Figure 37 shows the monthly pollution removal by trees in Wirral, demonstrating that this benefit is mostly delivered in summer, when deciduous trees are in leaf. The strong link between leaf area and air pollution removal manifests itself in inequitable provision of air pollution removal across areas of deprivation in Wirral: **the areas with the lowest leaf area receive the least benefit** (Figure 38).

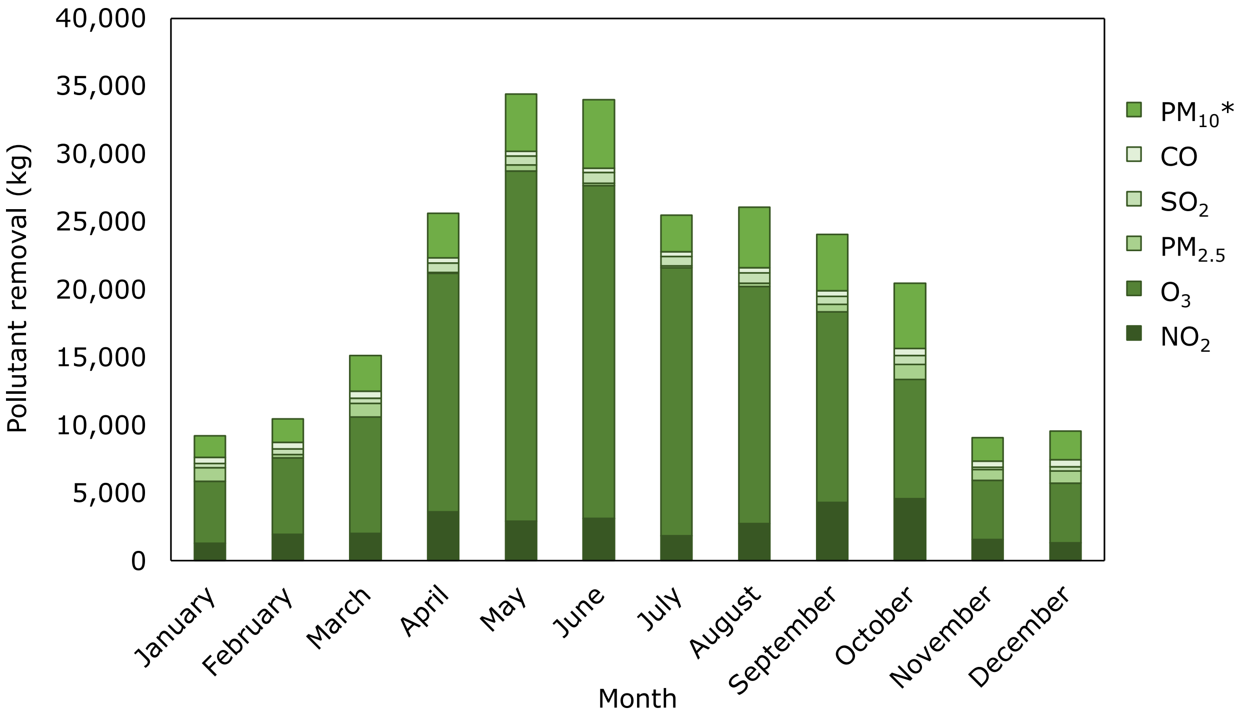


Figure 37. Monthly air pollution removal by trees in Wirral.

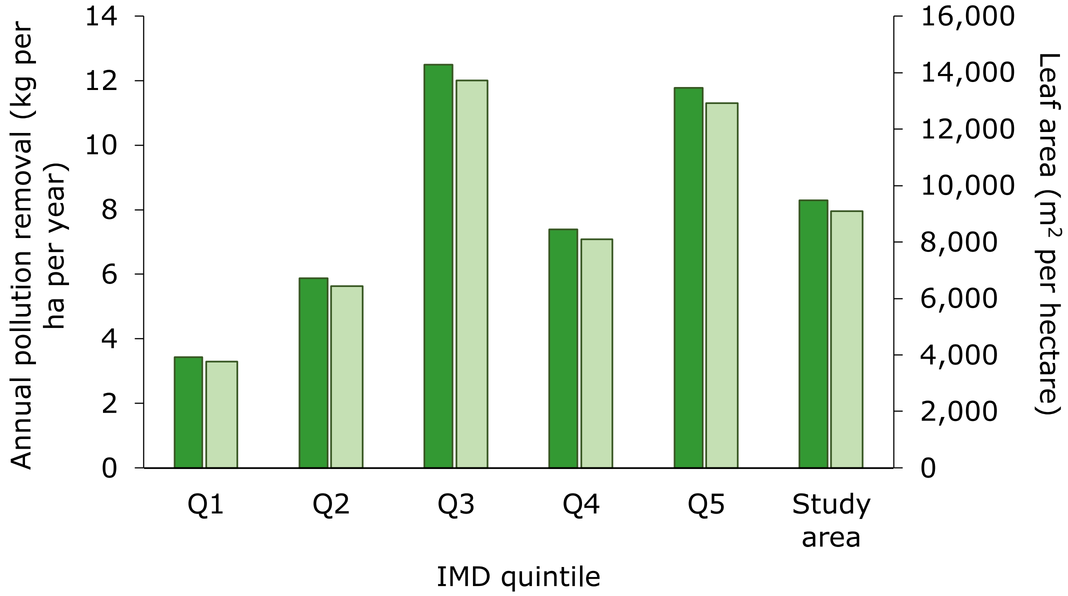


Figure 38. Annual air pollution removal per hectare, and leaf area per hectare, in each of the IMD quintiles and the overall study area.

Air pollution removal by Wirral's urban trees

Respondents to the survey said that clean air was one of the **top priorities** for management of trees in Wirral. The primary source of pollution in urban areas is from vehicular road transport, from exhausts and mechanical wear and tear. The concentration of air pollutants tends to be highest immediately on or adjacent to a busy road and decreases with increasing distance from the road until it reaches the background level at several hundred metres from the road (Hagler et al., 2011). A study for the British Lung Foundation and UK:100 found that people in **areas of higher deprivation** in Wirral experienced higher concentrations of NO_2 and $PM_{2.5}$ (Dajnak et al., 2011). This is combined with lower tree canopy cover and therefore lower provision of air pollution removal by trees.

The position and density of vegetation has a large impact on its effectiveness at removing air pollution (Defra, 2018). Trees that trap pollutants near their source, such as a closed canopy over a road, can increase rather than decrease concentrations. Trees that act as a barrier between the source of pollution and, for example, active travel routes, can reduce the concentrations that people are exposed to. Careful consideration of the mode of pollution reduction and the **location of trees in relation to the sources of pollution** can therefore achieve the desired reduction in concentrations (Janhäll, 2015; Pearce et al., 2021). The prototype GI4RAQ platform enables design of street vegetation to reduce exposure to emissions.

Some tree species can have a negative effect on air pollution by emitting gases called Volatile Organic Compounds (VOCs). When these combine with reactive oxides of nitrogen (NO_x) they can contribute to the production of other pollutants such as O_3.

Urban woodlands are particularly effective at absorbing particulate matter (Fowler et al., 2004; McDonald et al., 2007). The 2022 woodland natural capital accounts (ONS, 2022) estimated that in 2020 UK woodlands removed 310,400 tonnes of air pollution with an associated value to society of £1 billion.

The UK Centre for Ecology and Hydrology has developed an online Pollution Removal by Vegetation tool to enable people to explore how additional woodland planting would contribute to $PM_{2.5}$ removal, improve air quality and reduce health costs. **Incorporating small woodlands into urban design** would enable people to travel through on their way to school, work, or shopping, and to receive the numerous benefits provided during their day-to-day lives.

3.4.3 Carbon storage and sequestration

The issue

Anthropogenic emissions of carbon dioxide (CO_2) have resulted in a global increase in temperature and will cause further increases. The rise in temperature has serious and wide-range effects on our climate and on the whole planetary system. These effects are felt at the local level, and local organisations are taking action to reduce emissions and increase resilience. Wirral declared an Environment and Climate emergency in 2019 and through this committed to action to cut climate damaging pollution in line with global targets, develop resilience, and protect and enhance biodiversity.

How trees can help

Approximately half the dry weight of woody biomass in trees is carbon. As trees grow they lay down wood fibres, locking away carbon from the atmosphere in the process. As long as a tree is alive it can store and sequester carbon. If the tree dies and decomposes or is burned for fuel the stored carbon is released back into the atmosphere. As well as planting new trees for carbon sequestration, it is vitally important to maintain existing trees to ensure the carbon stored in them is stored for as long as possible.

As part of its 2019 climate commitment Wirral aims to double its tree canopy cover by planting 210,000 trees by 2030.

Wirral's trees

The total mass of carbon currently stored in Wirral's trees is **338,000 tonnes**. This is equivalent to 1.2 million tonnes of CO_2. Of the trees that were surveyed, the tree that stores the most carbon is a 24 metre tall ***Tilia x europaea*** with a DBH of 105 cm, located in a patch of woodland on a golf course near Eastham.

The carbon in trees can be valued within the framework of the UK government's carbon valuation method (BEIS, 2021). This is based on the abatement costs of meeting the UK's carbon reduction targets. There are three pricing scenarios: low, central and high. These are used to reflect uncertainties in determining future carbon values, including in relation to future fuel prices. Based on the central value carbon for 2022[11], the current value of the carbon stock contained in Wirral's trees is **£308 million**.

Figure 39 shows carbon storage and estimated tree numbers for the ten species that store the most carbon in Wirral. ***Acer pseudoplatanus, Quercus spp., Fagus spp., and x Cuprocyparis leylandii*** store the most carbon. These are all large trees that are dominant in Wirral's tree population.

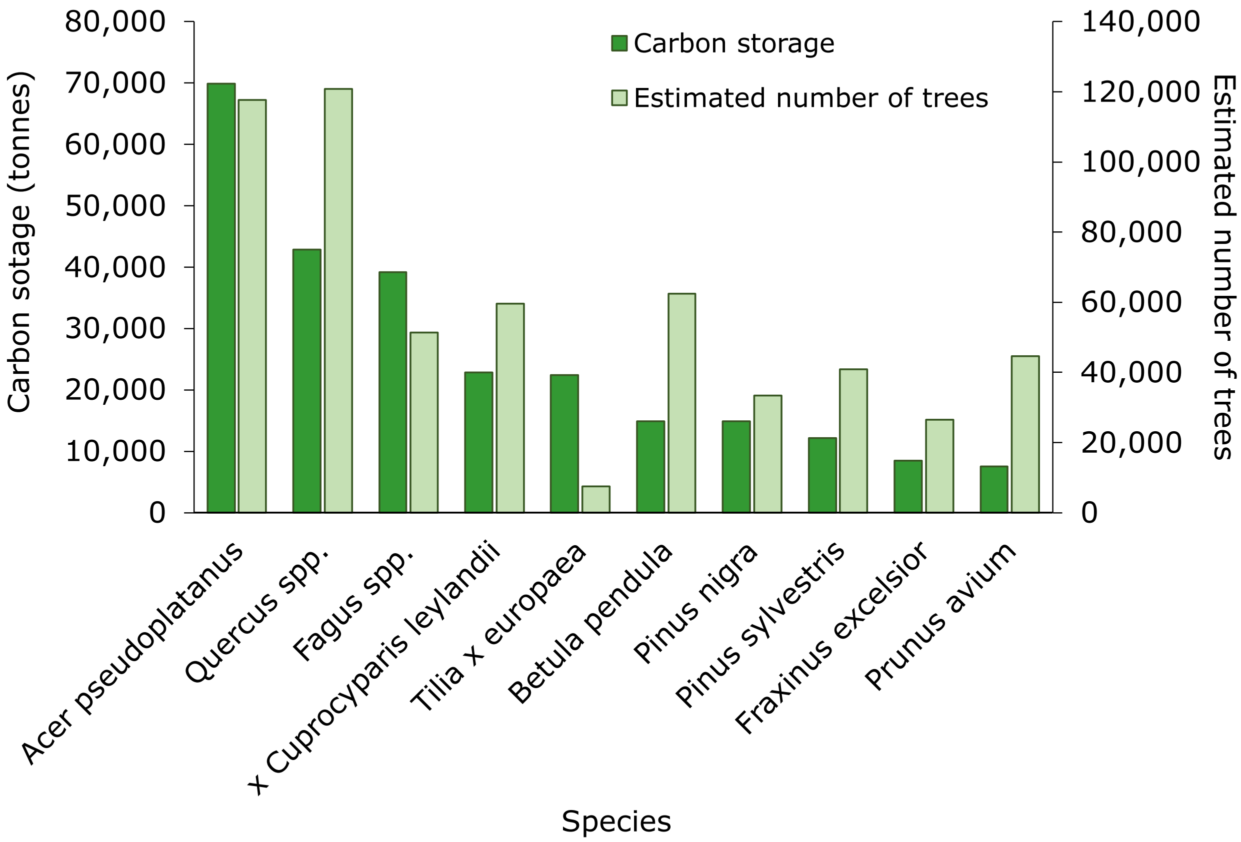


Figure 39. Carbon storage and estimated number of trees for the ten species that store the most carbon in Wirral.

Figure 40 shows carbon storage per hectare, and value per hectare, for each IMD quintile and for the study area. Quintile 3 has the highest carbon storage per

[11] The 2022 central value CO_2 is £248 per tonne (BEIS, 2021).

hectare. Quintile 3 has the highest proportion of trees with a DBH greater than 60 cm and a canopy spread greater than 10 metres (see Figure 15). It has the second highest canopy cover, and the second highest number of trees per hectare.

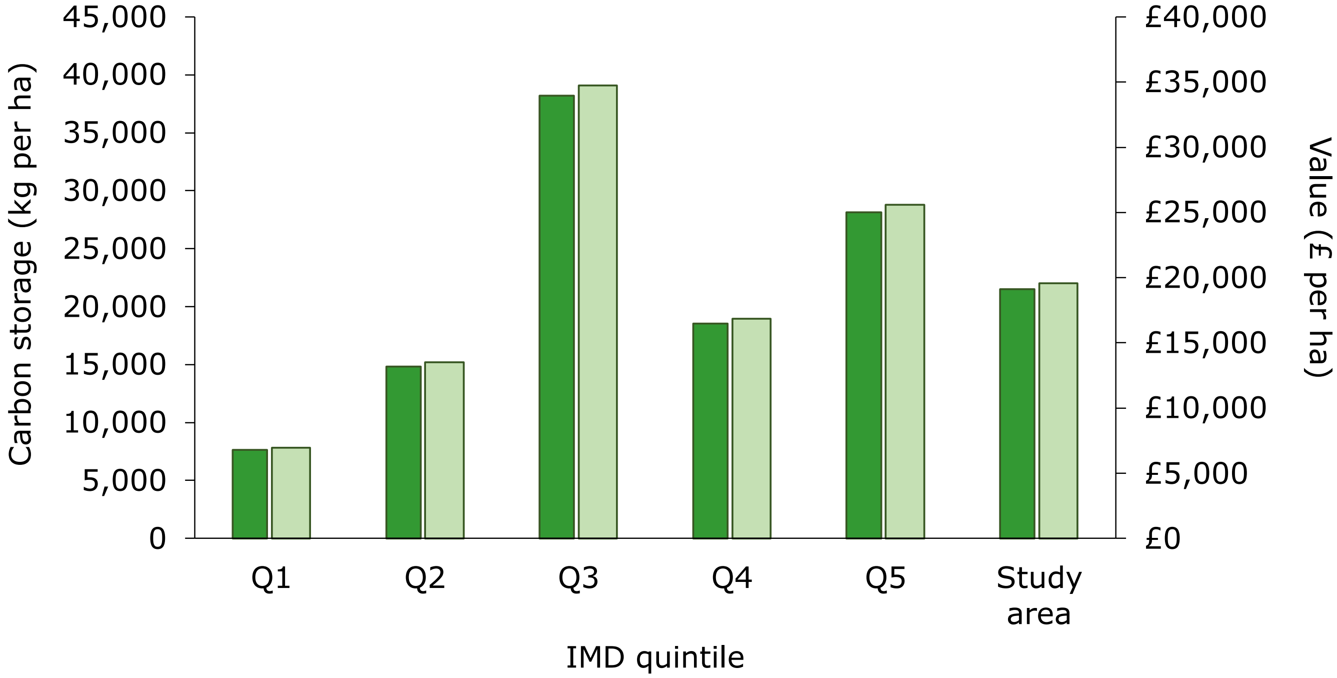


Figure 40. Carbon storage per area, and value per area, by trees in each IMD quintile and the study area.

Figure 41 shows the annual net carbon sequestration and estimated numbers of trees for the ten species that sequester the most carbon in Wirral. **Large stature, numerous trees dominate the top ten**, with the addition of *Betula pubescens*. Of the trees recorded during the survey, the tree which sequesters the most carbon each year is a 27 metre tall *Fagus* species, with a DBH of 86 cm. Carbon sequestration for most tree species increases with age (Stephenson et al., 2014), as the tree adds a similar thickness of wood each year to an increasing diameter (White, 1998). This means that on an individual basis the largest trees in a population tend to sequester the most carbon. However, new tree planting also has an important role to play. Once established young trees planted close together grow quickly and can sequester more carbon per area of land (Pugh et al., 2019).

They are also important as replacements for the old trees that will eventually be lost from the population.

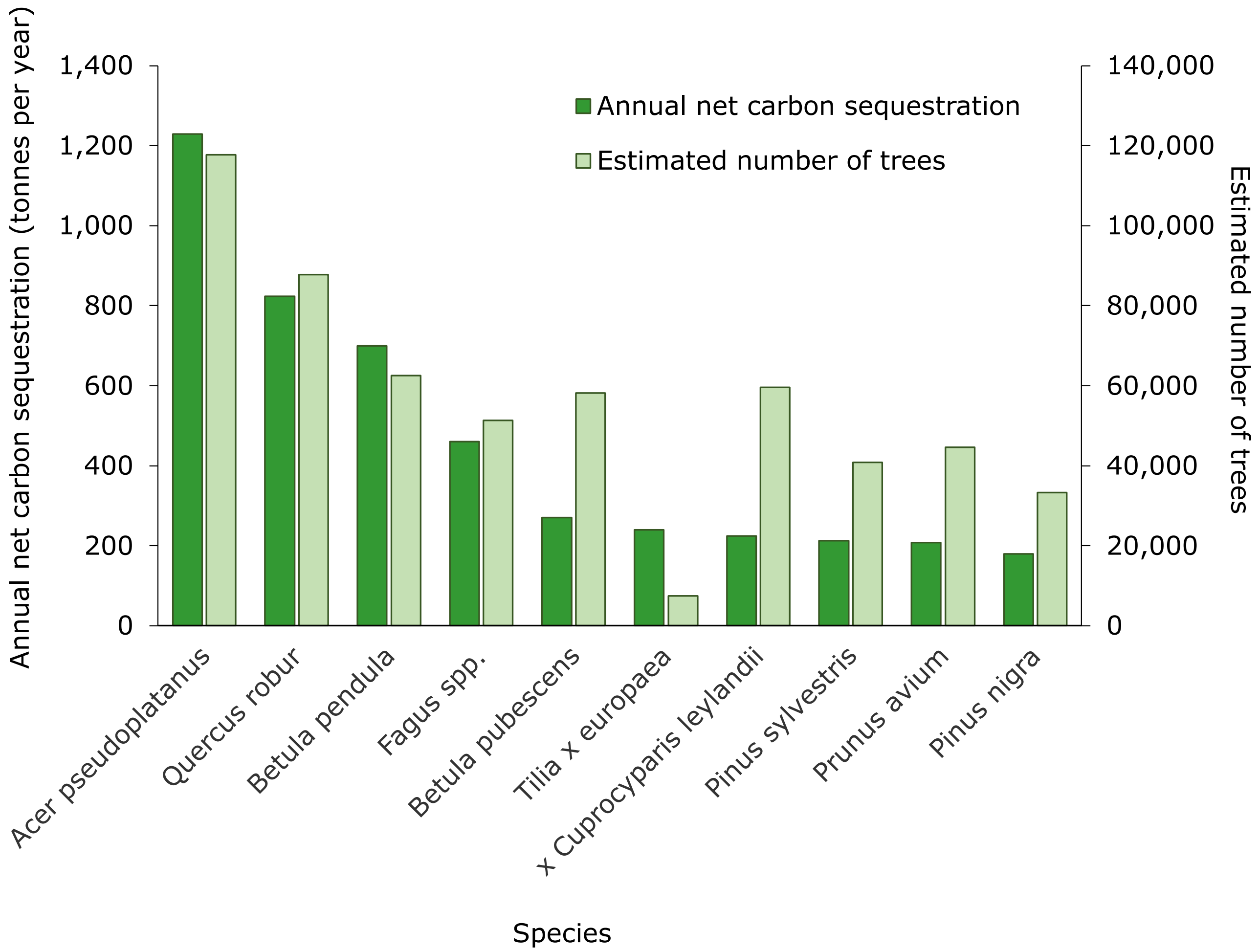


Figure 41. Annual net carbon sequestration and estimated number of trees for the ten tree species that sequester the most carbon in Wirral.

3.4.4 Habitat provision

The issue

The UK is in an ecological crisis having lost nearly half of its biodiversity since the Industrial Revolution due to the expansion of agriculture and built infrastructure. The UK now ranks in the bottom 10% of the world's countries for its biodiversity and is the worst ranking country from the G7 (Natural History Museum, 2021). Climate change may accelerate the decline of biodiversity further: up to 37% of species present in 20% of the Earth's terrestrial surface will be 'committed to extinction' by 2050 (Thomas et al., 2004).

Action is needed and supporting nature in UK cities can be part of the solution. This can help create habitats for wildlife species as well as strengthening citizen's connection with nature, and so improving their health and wellbeing (Sandifer et al., 2015).

How trees can help

Trees are instrumental for creating safe habitats within towns and cities for other flora and fauna (Smith et al., 2006; Nielsen et al., 2014), particularly during spring to autumn when trees are in full canopy and produce flowers and fruits and when migrating species are present (Paker et al., 2014).

Trees located in different land uses, such as streets, domestic gardens or parks can all play a significant role (Lundquist et al., 2022). A greater wildlife richness is normally recorded in urban areas with a greater number of tree species (Paker et al., 2014). Native tree species are considered to have a higher biodiversity value (Helden et al., 2022) however non-native tree species can be also useful in housing and generating food for wildlife, such as for pollinators (Baldock et al., 2015). Larger and older trees have also been found to be more beneficial for wildlife (Knight et al., 2012; Nielsen et al., 2014). Therefore, aiming for greater diversity in the urban forest, in terms of the range of planting locations, species and tree sizes and ages, is required to offer the greatest range of possible habitats.

Wirral's trees

Wirral is very rich in its biodiversity: Grey seals and many species of birds visit the Dee and Mersey estuaries each year; the Belted Beauty moth appears in the North Wirral Coastal Park, its only location in England, and the extremely rare Natterjack Toad is returning to the Red Rocks near Hoylake. This is considered one of the area's biggest assets and an action plan is in place to focus resources to conserve and enhance biodiversity (WBPTG, 2003).

The urban forest of the Wirral can play a significant role in this aim. The current provision of biodiversity value by Wirral's trees was assessed for three aspects of biodiversity: foliage invertebrate richness, pollen and nectar provision, and fruit and seed provision. These indicators can be useful in future planting aimed at boosting the urban forest's value to wildlife, by helping target species with high value which are low in abundance.

The information on the number of invertebrates associated with tree species was gathered from Kennedy and Southwood (1981). The information on the species' ability to provide pollen, nectar, fruits, and seeds to wildlife was rated following the ranking attributed by Alexander et al. (2006), which scores trees from a high value (5) to a low value (0) (Table 13). While these metrics provide a useful indicator of the relative biodiversity value of different tree species, it is important to note that they are gathered from various sources using different methods and from different locations, and most importantly are not specific to trees in urban areas.

Of the tree species considered, the most abundant species in Wirral (*Acer pseudoplatanus*) is one of the worst for supporting insects (Figure 42). However ***Quercus robur*** and ***Betula pendula*** also highly abundant and are some of the best. The best species for supporting insects from those considered is ***Salix caprea***, supporting in total 450 species. This species only represents 1% of the tree community, so there is scope to improve the delivery of this benefit.

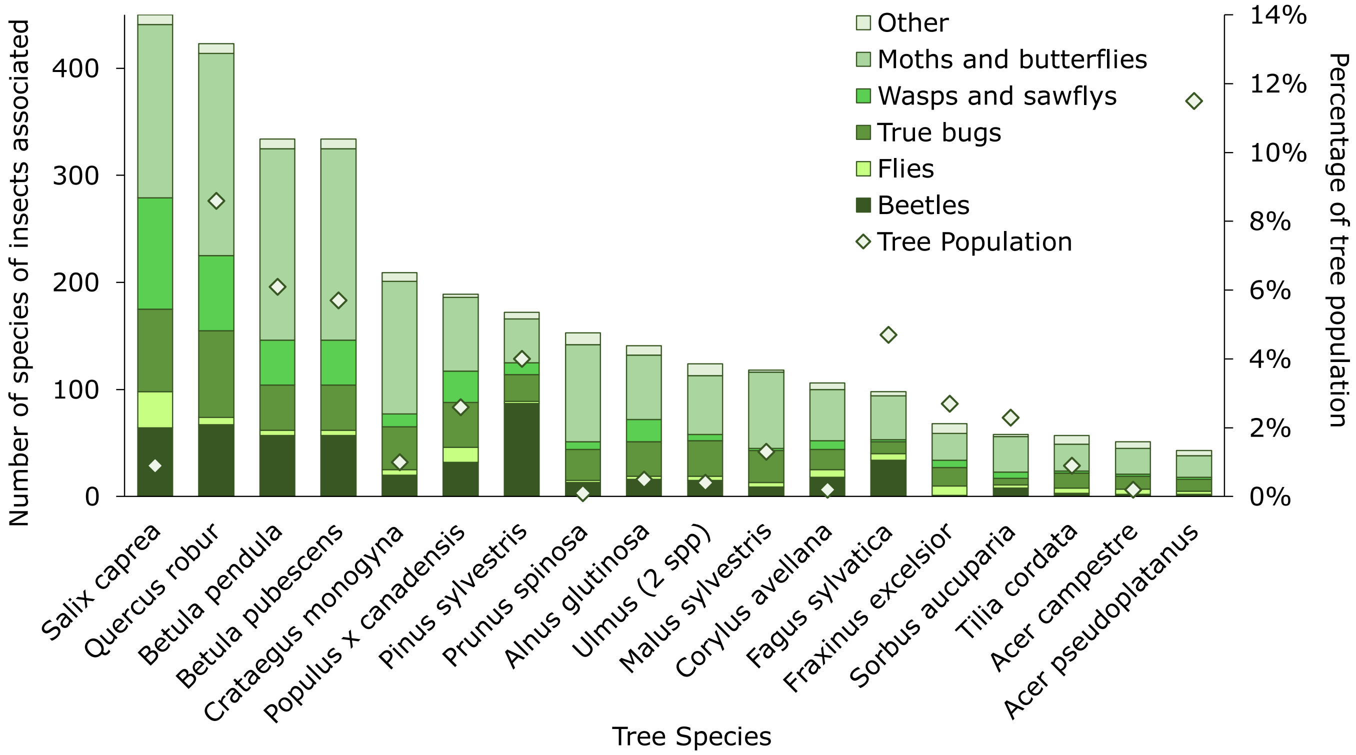


Figure 42. Foliage invertebrates supported by tree species, and tree species abundance within Wirral's population.

Of the five most common tree species in Wirral only ***Acer pseudoplatanus* ranks relatively highly for the provision of pollen and nectar**. Increasing the proportion of ***Ilex aquifolium***, ***Salix spp.*** and ***Crataegus monogyna*** may improve the provision of pollen and nectar. All but one of the five most common tree species are rated highly as providers of fruits/seeds. Increasing the populations of ***Quercus spp.*** and ***Prunus spp*****.** would enhance this food source further. Note that *Prunus spp.* and *Crataegus spp*. perform well at supplying nectar and pollen as well as seeds and fruits.

Table 13. Ranking for the provision of pollen and nectar and fruits and seeds for selected tree species, species groups, or genera[12] in Wirral.

Species	% population	Provision of pollen & nectar	Provision of fruits & seeds
Betula spp.	13.5	1	4
Acer pseudoplatanus	11.5	4	1
Quercus robur and Q. petraea	10.3	1	5
Prunus spp. (cherries)	7.3	4	5
Fagus spp.	5	1	5
Sorbus spp.	4.4	4	4
Pinus sylvestris	4	1	4
Ilex spp.	3.6	5	4
Fraxinus excelsior	2.7	1	1
Populus spp.	2.7	1	1
Malus spp.	2	4	4
Tilia spp.	1.7	4	1
Crataegus spp.	1.5	5	4
Prunus spp. (plums)	1.3	4	4
Salix caprea and S. cinerea	1.3	5	1
Alnus spp.	1.3	1	4
Salix fragilis, S. alba and Salix sp.	1.2	5	1
Taxus baccata	0.4	1	4
Ulmus spp.	0.4	1	1
Pyrus communis	0.3	4	3
Acer campestre	0.2	4	1
Castanea sativa	0.2	1	5
Corylus avelana	0.2	1	3
Larix decidua	0.2	1	4

[12] Alexander et al. list species, species groups, and genera in their wildlife value rankings.

3.5 Replacement Cost and Amenity Value

3.5.1 CTLA valuation

Wirral's urban forest has an estimated replacement value of £17 million according to the CTLA Appraisers (1992) valuation method (Cullen, 2007). This is the estimated cost of replacing all of Wirral's trees should they be lost to disease, development, or other removal. This method does not take into account the condition or amenity value of the trees; the trunk area is used as a proxy for tree size. See Appendix A for more details.

3.5.2 CAVAT valuation

The trees in Wirral's urban forest have an estimated public amenity asset value of **£22.6 billion**[13]. This valuation was calculated using an amended version of CAVAT Full Method (FM) (Doick et al., 2018), extrapolated from the measured trees to the whole study area. This method takes into account the size and condition of trees, their public visibility, and their life expectancy. See Appendix A for further details on the CAVAT method. ***Acer pseudoplatanus*** represents 12% of the measured trees, and contributes 21% of their total amenity value, at an estimated **£1,186,000**. The tree with the single largest amenity value is a 24 metre tall ***Tilia x europaea*** with a DBH of 105 cm, just 3% of the crown missing, and between 95 and 99% of the existing crown in good condition. It's CAVAT value is **£159,672**. This tree is located on a golf course near Eastham, with no public right of way. Table 14 gives CAVAT values for the ten most valuable measured species in the survey, based on measured data only.

[13] For comparison with previous i-Tree Eco reports, the total CAVAT value of the measured trees, using the Quick Method, is £4.5 million.

Table 14. CAVAT values of the ten most valuable species, based on measured trees only, not extrapolated to the whole study area.

Species	CAVAT value[14]	Percent of total measured value	Percent of measured population
Acer pseudoplatanus	£1,185,857	11.5%	20.6%
Quercus robur	£595,932	8.6%	10.4%
Pinus nigra	£566,508	3.3%	9.8%
Fagus sylvatica	£546,580	4.7%	9.5%
Tilia x europaea	£333,882	0.7%	5.8%
Pinus sylvestris	£315,803	4.0%	5.5%
Betula pendula	£304,135	6.1%	5.3%
x Cuprocyparis leylandii	£180,497	5.8%	3.1%
Salix fragilis	£150,796	0.6%	2.6%
Prunus avium	£131,130	4.4%	2.3%
All Other Species	£1,440,696	50.2%	25.0%

Figure 43 shows the extrapolated CAVAT value per unit area for each IMD quintile and for the study area. Trees in quintile 1, the most deprived area of Wirral, have the lowest CAVAT value, and trees in quintile 5 have the highest CAVAT value, closely followed by quintile 3. Quintile 5 has the highest proportion of publicly visible trees, and quintile 3 has the highest proportion of trees with a DBH exceeding 60 cm. Quintile 3 also has the highest proportion of Forest / woodland land use, which has the highest CAVAT value of the recorded land uses (Figure 44).

[14] CAVAT values for species are based on measured trees only, not extrapolated to the whole study area.

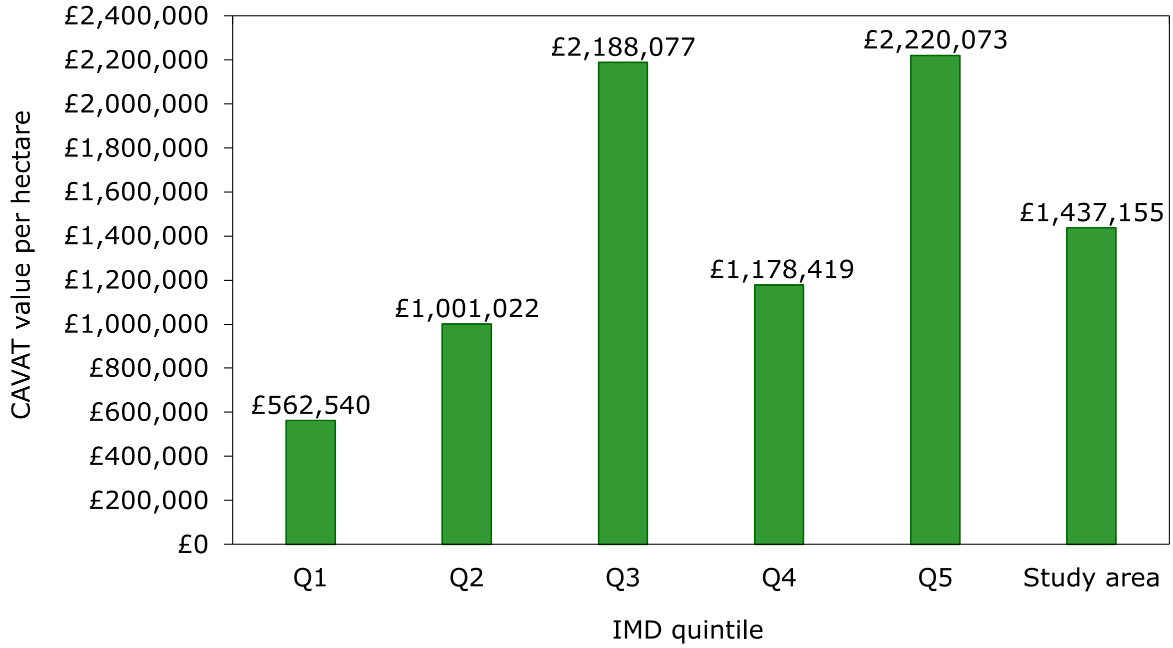


Figure 43. Extrapolated CAVAT values per hectare for each IMD quintile and the study area.

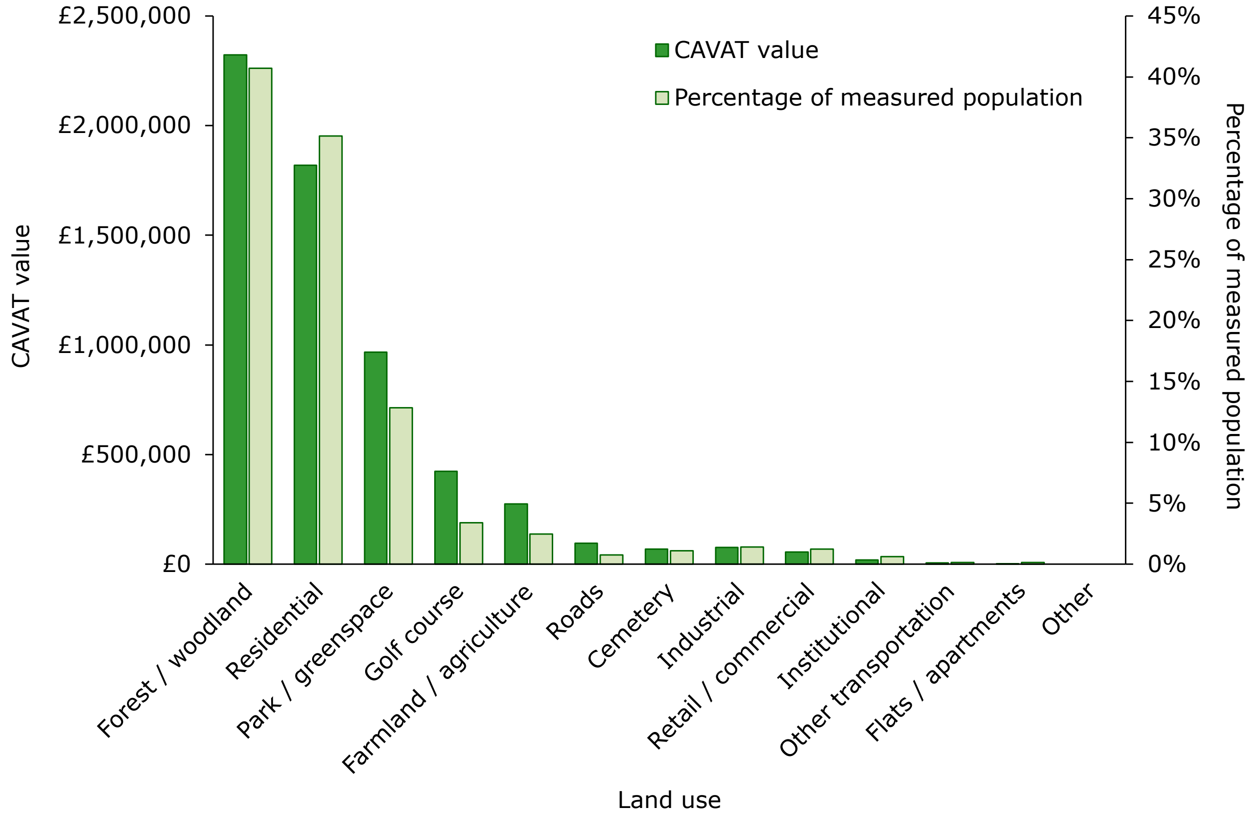


Figure 44. CAVAT value (for measured trees only) and tree numbers as percentage of total in recorded land use categories.

3.6 Pests and Diseases

Pests and diseases are a serious threat to tree populations. Damage and death to trees reduces the benefits they provide to people and has a further economic burden because of the requirement to manage unhealthy and potentially unsafe trees. It is important to consider the impacts of existing and potential pests and diseases when planning and managing an urban forest. It is likely that climate change will result in the introduction of pests and diseases not yet present in the UK. Warmer temperatures 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 natural enemies (Wainhouse and Inward, 2016). 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 (Frederickson-Matika and Riddell, 2021).

3.6.1 Pests and diseases in Wirral

Chalara ash dieback (*Hymenoscyphus fraxineus*) is present on the Wirral. The i-Tree Eco survey found a relatively low proportion of *Fraxinus* species in the tree population, 2.9% of the total (an estimated 26,000 trees). Data derived from the 2007 Countryside Survey and ecological land classification (Maskell et al., 2013a, 2013b, 2013c) shows a medium prevalence of individual ash trees in rural areas of the Wirral peninsula (10 trees per km^2), a relatively high prevalence in linear woody features (hedgerows and belts of trees, 0.9 km per km^2), and generally low prevalence of ash woodland (0 to 0.2 hectares per km^2) with scattered higher concentrations (1 to 5 hectares per km^2) (see Appendix C for more details). This mixed picture suggests that the impacts of Chalara ash dieback will be experienced unequally across the peninsula. Wirral's Tree, Hedgerow and Woodland Strategy 2020-2030 covers Chalara ash dieback in detail and recommends that trees are retained wherever possible. There is evidence to suggest that early pruning of infected branches can help to maintain the vitality of young trees (Marciulyniene et al., 2017). The amenity (CAVAT) value of the ash trees measured in the survey is £63,813. The amenity value of all the ash trees in the area will be many times this number. Table 15 gives condition ratings of *Fraxinus excelsior* in Wirral's tree population.

Table 15. Condition ratings of *Fraxinus excelsior* in Wirral's tree population.

Condition rating	Percentage of *Fraxinus excelsior* population
Excellent	0%
Good	22%
Fair	28%
Poor	17%
Critical	17%
Dying	11%
Dead	5%

Dothistroma needle blight (*Dothistroma septosporum*) is a fungus affecting conifer trees, in particular the *Pinus* genus. It causes needle defoliation, reducing the growth of the tree and sometimes causing death. It is primarily a concern for commercial forestry, but since *Pinus* comprises nearly 8% of Wirral's tree population, it has the potential to be an important disease in this area. The fungus is affecting pine stands in nearby Delamere forest in Cheshire (Forestry Commission, 2016). It is a regulated pest, with mitigation measures in place, and the likelihood of it spreading to its maximum extent is low (Defra, 2021), but being aware of the disease and monitoring for its presence in Wirral would be worthwhile. See Appendix C for more details.

Ramorum disease, also known as sudden oak death, is caused by the algae-like water mould *Phytophthora ramorum*. It is also present in Delamere forest (Forestry Commission, 2016), and has a high likelihood of spreading to its maximum extent, even with control measures in place (Defra, 2022c). Ramorum is a highly destructive disease, causing damage and death to more than 150 plant species. It has the potential to affect 43% of Wirral's tree population. See Appendix C for more details.

Sooty bark disease of maple is an increasingly common fungal disease affecting *Acer* species, especially *A. pseudoplatanus*, which represents 12% of Wirral's tree population. It is caused by a fungus called *Cryptostroma corticale* which enters the tree through bark wounds and results in prolific growth of spores under the bark, loss of bark from the trunk, and ultimately dieback and death of the tree. The spores have the potential to cause an inflammatory lung disease in people working with affected timber, or people with compromised immune systems. Monitoring for its presence in Wirral would be a worthwhile undertaking.

These and other pests and diseases have been considered in terms of the likelihood of their spread to Merseyside, the percentage of Wirral's tree population they could affect, and the estimated CAVAT value of those trees.

Table 16 shows the risk matrix used to assess the probability of a pathogen affecting trees from a single genus in Wirral's tree population forest. Table 17 shows the risk matrix for pathogens that affect trees in multiple genera. In both cases, the higher the percentage of the tree population and the more likely that the pathogen is already present in the UK, the greater the probability of that pathogen having an adverse impact in Wirral. Many pests and diseases can infect a whole range of tree species but only the species recorded in the i-Tree survey were considered here.

Table 16. Risk matrix used for the probability of a pest or disease becoming prevalent in Wirral's tree population on a single genus (one or more species).

Prevalence	**% Population**		
	0-5	6-10	>10
Not in UK			
Present in UK			
Present in Merseyside			

Table 17. Risk matrix used for the probability of a pest or disease becoming prevalent in Wirral's tree population on multiple genera.

Prevalence	**% Population**		
	0-25	26-50	>50
Not in UK			
Present in UK			
Present in Merseyside			

Table 18 gives an overview of some of the established and emerging pests and diseases that could have a significant impact on Wirral's urban forest. The percentage of the tree population at risk has been colour coded to highlight the relevant risk from each pathogen.

Table 18. Pests and diseases with potential impact on Wirral's trees. CAVAT values are for measured trees only and are not extrapolated to the study area.

Pest/Disease	Tree species affected	Prevalence in the UK	Prevalence in Merseyside	Mitigated risk of spreading to Merseyside (or UK if not already present)	Tree population at risk (%)	CAVAT value of trees (£)[15]
Acute oak decline	*Quercus spp*. including *Q. ilex, petraea, robur*	Southern, eastern and central England; south Wales	Not present	High	12%	£785,896
Asian longhorn beetle	Many broadleaf species (see Appendix C)	Not present (outbreak in Kent eradicated)	Not present	Low	56%	£3,941,132
Bronze birch borer	*Betula spp.* including *B. pendula, utilis*	Not present	Not present	Low	13%	£477,268
Chalara ash dieback	*Fraxinus spp*. including *F. excelsior, angustifolia, ornus, chinensis, mandshurica*	Widespread (low prevalence in east)	Present	Already present	3%	£63,813
Citrus longhorn beetle	Many broadleaf species (see Appendix C)	Not present (numerous interceptions)	Not present	Low	53%	£3,145,328

[15] Measured trees only, not extrapolated to the study area.

Pest/Disease	Tree species affected	Prevalence in the UK	Prevalence in Merseyside	Mitigated risk of spreading to Merseyside (or UK if not already present)	Tree population at risk (%)	CAVAT value of trees (£)[15]
Dothistroma needle blight	*Pinus spp.* including *P. nigra, contorta, sylvestris, ponderosa, muricata* and *Larix spp*.	Widespread	Unknown, but present nearby in Delamere, Cheshire	High	8%	£1,007,067
Emerald ash borer	*Fraxinus spp*. including *F. americana, excelsior*	Not present	Not present	Medium	3%	£63,813
European mountain ash ringspot associated virus	*Sorbus spp.*	Scotland	Unknown	Low	4%	£42,980
Horse chestnut bleeding canker	*Aesculus spp*. including *A. hippocastanum, x carnea*	Widespread	Unknown	High	0.2%	£33,447
Oak processionary moth	*Quercus spp*. including *Q. petraea, robur*	Greater London and surrounding counties	Not present	Medium	12%	£785,896
Pine processionary moth	*Pinus spp., Cedrus atlantica, Larix decidua*	Not present (intercepted in southern England)	Not present	Medium	8%	£1,045,076

Pest/Disease	Tree species affected	Prevalence in the UK	Prevalence in Merseyside	Mitigated risk of spreading to Merseyside (or UK if not already present)	Tree population at risk (%)	CAVAT value of trees (£)[15]
Phytophthora kernoviae	Many broadleaf species (see Appendix C)	Scotland, England, and Wales (most cases in Devon and Cornwall)	Unknown, but present nearby in NW England	Low	17%	£1,317,684
Ramorum disease	Over 150 plants (see Appendix C)	Scotland, England, and Wales, mostly in western regions	Unknown, but present nearby in Delamere, Cheshire	High	43%	£3,118,840
Red-necked longhorn beetle	*Prunus spp., Quercus spp., Olea europaea, Populus spp.*	Not present (one case intercepted)	Not present	Medium	21%	£1,016,198
Sooty bark disease of maple	*Acer spp.*	Present	Unknown (unconfirmed report in Liverpool)	Medium	14%	£1,287,732
Xylella	Wide range of genera including *Quercus*, *Ulmus*, and *Platanus* (see Appendix C)	Not present (intercepted)	Not present	Low	21%	£1,408,343

Management to reduce the risk of tree pests and diseases

A more diverse tree population is more resilient to the impacts of pests and diseases. Genetically similar trees have susceptibility to damage from biotic and abiotic stresses (Kendal et al., 2014). Having a **wide variety of tree species** means that the loss of a single species has a lower impact (Lohr, 2013), and reducing the dominance of a few species also reduces the risk of spread of pests and diseases through a population (Civitello et al., 2015). **Optimising the growing conditions and therefore health of the trees in the population** also increases their resilience. This will become increasingly important in our future climate, as both environmental stresses and the presence of pests and diseases increase (Riddell and Frederickson-Matika, 2021; Frederickson-Matika and Riddell, 2021).

Where diseases such as Ramorum are present in a tree population, the appropriate action is **containment and removal** of the affected trees. For diseases which are hard to contain, such as Chalara ash dieback, **management of affected trees and monitoring for apparent resistance** may help to retain some of the population. However, prevention is often better than management. Many pests and diseases which are not currently present in the UK, such as Asian longhorn beetle, have the potential to damage many species. The greatest risk of introduction is on imported plant or packing material. **Monitoring imported material and existing trees** for the presence of pests and diseases helps trigger a fast response to eradicate the pest before it becomes a problem, and also helps to inform research targeted at combating emergent threats.

Two initiatives have been established to help researchers understand the presence and spread of tree pathogens in the UK:

Observatree (https://www.observatree.org.uk/) is a citizen science early-warning system for tree health.

TreeAlert (https://treealert.forestresearch.gov.uk/) is the online system for reporting and gathering information about existing pests and diseases on trees.

4 Recommendations

Equitable provision of benefits

Trees and the benefits they provide are not distributed equitably across Wirral. Seek out the voices of those people who are less often heard, such as people living in more deprived areas of Wirral. Increase planting (and therefore benefit provision) in areas that are lacking in canopy cover. Look to plant in areas with high deprivation and those which experience high pollution, surface flooding, limited greenspace, or lack of shade.

Undertake an assessment of recent trends in canopy cover across the Wirral, including the causes for such change. Where recent trends are for declining cover then greater effort can be focused to reverse the causes of change, helping Wirral to reach its 2030 canopy cover target.

Wide range of benefits

As well as planting trees for carbon storage and sequestration, consider the other benefits that trees provide. Consider using Forest Research's "replacement rates" workbook[16] to select tree species for provision of multiple benefits.

Structure

Large trees provide the greatest quantity of benefits. Retain large, mature trees wherever possible. Aim to make large, mature trees a part of new developments rather than removing and replacing them.

[16] Selecting tree species for ecosystem service provision: Ecosystem service provision workbook. Available at: https://www.forestresearch.gov.uk/research/quantification-and-valuation-of-benefits-provided-by-urban-trees/selecting-urban-trees-for-ecosystem-service-provision/.

Plan for replacement of trees that will eventually be lost. Where possible, plant species that can reach large stature so that the benefits currently provided by these trees will be replaced.

Trees in development

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 new guide to delivering trees in planning and development[17] contains recommendations for ensuring that the value of trees is recognised and reflected in new developments.

Set up community tree care schemes to encourage engagement by local people and help to ensure the good health of young trees.

Take opportunities to create areas of accessible urban woodland to bring benefits to people in their day-to-day lives.

Planting

Protect and enhance tree cover on private land (agricultural, private gardens, commercial, industrial) by engagement with local communities, businesses, and landowners. Tree planting on agricultural land has the potential to help Wirral reach its 2030 canopy cover target.

Many of the respondents to the people survey said they could see trees in private gardens from their home, and that they would be willing to plant trees in their garden, or were already doing so. However, people ranked trees in gardens low in terms of the contribution they made in Wirral. Engage people in planting and caring for trees in their garden and in recognising the value of garden trees as an important part of the urban forest.

[17] https://www.tdag.org.uk/trees-planning-and-development.html.

Carbon storage and sequestration

Ensure the survival of existing large trees to maintain the carbon storage and sequestration benefit they currently provide. Continue to plant new trees to replace the ones that will eventually be lost, and to increase canopy cover.

Find long-term uses for felled or dead trees, such as standing deadwood, sculptures and carvings, street and park furniture, or seasoning as native hardwood for sale. Chip or season for firewood only if there is no other use for the timber, so that the carbon is stored for as long as possible.

Pests and diseases

Establish a tree monitoring programme to give early warning of pests, diseases, and threats to Wirral's trees. This could be in the form of a community engagement and involvement opportunity, a refreshment of the Tree Warden scheme, or a citizen science training and monitoring programme through Observatree.

Diverse urban forests are more resilient to pests and diseases. When trees are removed, plant replacements that increase species diversity. Use the Right Trees for Changing Climate database, the TDAG species selection guide, and the Climate Matching Tool in conjunction with the Ecological Site Classification tree selection tool to find species that are likely to thrive in Wirral's future climate.

Adopt best practice guidelines for plant biosecurity to minimise the likelihood of introducing pests and diseases through plant and plant material imports.

Healthy trees are more resilient to pests and diseases. Plant trees using best practice, focus on establishment, and ensure good aftercare to maintain healthy trees. Establish an Internet of Things network of soil moisture sensors to determine whether young trees require watering. Encourage community care (particularly watering) of young trees through communication, campaigns, signage, and QR codes linked to websites providing guidance and information.

Appendix A

Supplementary information on methodology

Sampling

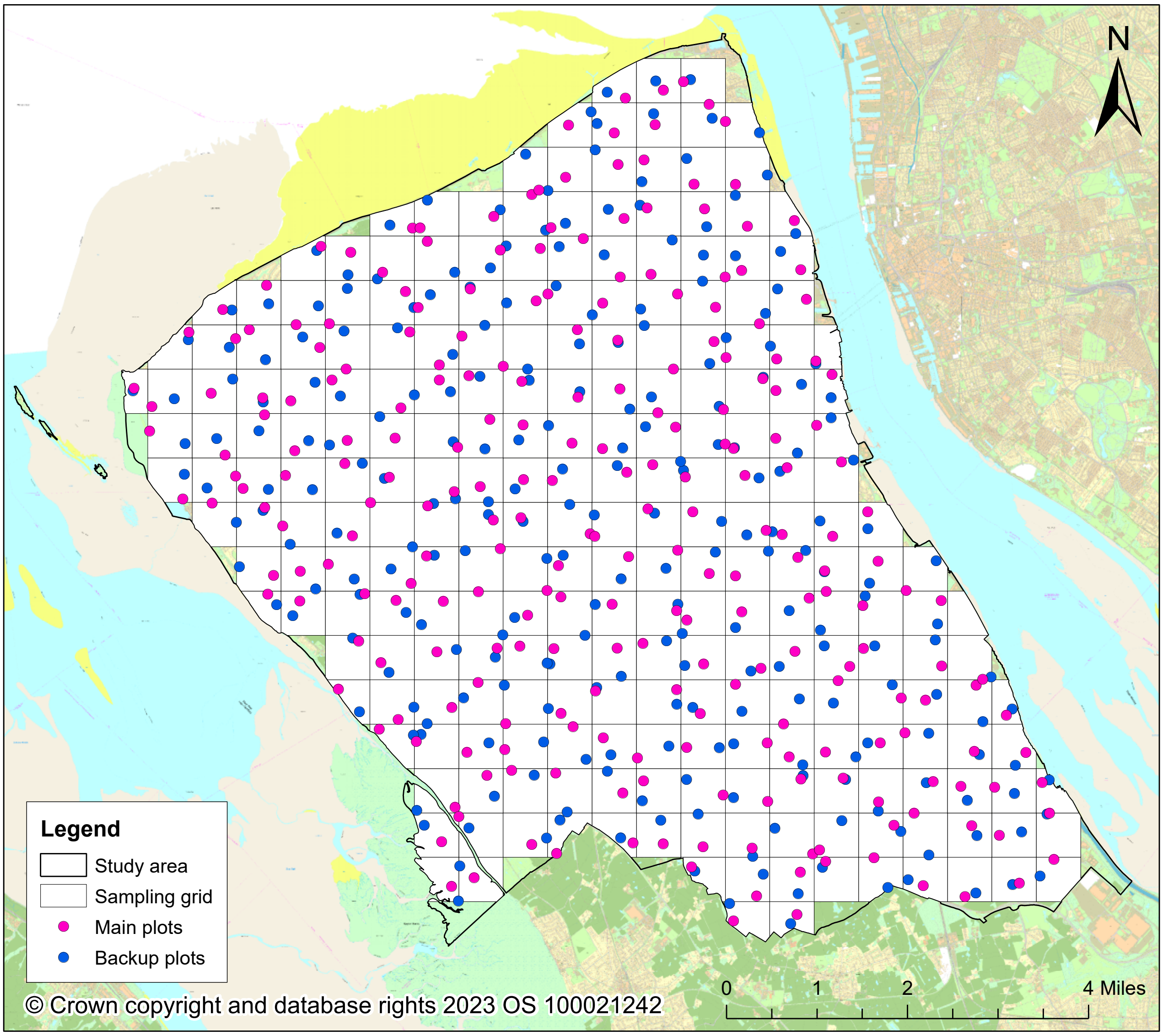


Figure 45. Map of study area, sampling grid, main and backup plots for the Wirral i-Tree Eco study.

People survey results analysis

Data cleaning and analysis were carried out in R (Version 4.2.1) with data visualisations created using plotly (Sievert, 2020) and ggplot2 (Wickham, 2016). Questions were analysed with linear or generalized mixed linear models depending on the outcome variable (continous score or binomial response) using the lme4 package (Bates et al, 2015). For questions with multiple responses the sub-question was fit as a fixed effect covariate so that the scores between statements could be compared. Age, gender and IMD quartile were also fit as fixed effect covariates with participant ID as a random effect. Age, gender and IMD quartile were tested for interactions with sub-question and the interaction term retained if $p < 0.05$.

Age was fit as a continuous predictor, with gender and IMD quartile as categorical predictors. Those who selected 'prefer not to say' for their gender had this value set to missing for the purposes of analysis as there were too few participants in this category to make meaningful comparisons from.

After obtaining the best model fit the significance of fixed effect predictors was tested using Type-II ANOVA from the car package (Fox and Weisberg, 2019). Main effects were considered statistically significant if $p < 0.05$. Estimated marginal means were then extracted from the model using the emmeans package (Lenth, 2022) and pairwise comparisons made using the multcomp package (Hothorn et al, 2008). The Tukey method was used to adjust the p-values and correct for multiple testing.

Land uses

Land use category	Description
Farmland / Agricultural	e.g. Cropland, pasture, vineyards, nurseries, farms
Retail / Commercial	e.g. Shops, businesses, commercial services, distribution, storage, parking not associated with housing or institutions
Industrial	e.g. Factories, manufacturing
Cemetery	Any small unmaintained areas within cemetery grounds
Forest / woodland	Does not include patches of woodland within other land uses, e.g. on golf course. Those are classed by the containing land use.
Golf Course	Golf course
Institutional	Schools, hospitals, surgeries, government buildings, colleges, etc.
Flats / apartments	Buildings for multiple households
Park	Unmaintained and developed (maintained) areas
Residential	Buildings for single households (terraces, detached, semi-detached, etc.)
Roads	Motorways, major roads, town centre roads, country roads and their verges
Other Transportation	Railways and stations, airports, bus stations, etc
Utility	Power generation or distribution, sewage treatment, reservoirs, flood control
Vacant	Land with no clear intended use. Includes forest-like areas. Classify vacant/abandoned buildings on their original use.
Water/Wetland	Streams, rivers, lakes, natural or constructed. Classify small constructed pools based on adjacent land use.
Other	Used sparingly

Ground covers

Ground cover category	Description
Buildings	All buildings including sheds, garages, etc. including those with green roofs
Cement	Pointing, mortar, concrete etc.
Tar	Tarmac / asphalt (pavements, roads, driveways, etc.)
Rock	Pervious rock surfaces such as gravel, brick, flagstone walkways or patios, paved areas, gravel, wide stone walls
Other impervious	Any hard surfaces that don't fit into other categories, e.g. decking; large solid rock outcrops, swimming pools, man-hole covers, artificial turf
Bare soil	Bare ground, naturally occurring sand
Mulch / plant matter	Bark chip, leaf litter under trees and shrubs, other organic mulch
Unmaintained grass	Grass that doesn't get cut
Grass	Grass that gets cut or mown, including long grass on roadside verges that are cut once per year
Herbaceous plants and ivy	Any plants that are not grass, a 1m tall shrub, or a tree
Water	Natural ponds, rivers, reservoirs, lakes, sea etc. Excludes temporary standing water. Artificial ponds with impervious lining should be classed as Other impervious.

Shannon-Wiener Diversity Index and Evenness

The Shannon-Wiener diversity index is calculated as:

$$H = -\sum [p_i \times ln(p_i)]$$

Where H is the Shannon-Wiener index and p_i is the proportion of individuals of species i in the whole population:

$$p_i = \frac{n}{N}$$

where n is the number of individuals of a single species, and N is the total number of individuals in the population.

Evenness is calculated as:

$$E = \frac{H}{\ln(k)}$$

Where E is evenness, H is the Shannon-Wiener index, and k is the number of species in the population.

Carbon storage and sequestration

Calculations of carbon storage and sequestration use tree species, DBH, total tree height, percentage of crown in good condition, and crown light exposure data. Carbon storage is estimated by multiplying above- and below-ground tree biomass by 0.5. Carbon sequestration is estimated by incrementally increasing the DBH of trees in the model based on an estimated annual growth rate.

Growth rate is estimated using a base growth rate, the length of the local growing season, species-specific growth rates, tree competition (crown light exposure), tree condition, and tree height.

Gross carbon sequestration is the total amount of carbon taken up by trees each year. An estimate of the release of carbon due to decomposition of dead trees is subtracted from this to give net carbon sequestration. More details are given by Nowak (2020).

Air pollution Removal

Air pollution removal estimates are based on modelling of gas exchange and particulate matter interception by trees, shrubs, and grass. i-Tree Eco estimates the hourly dry deposition of air pollutants based on tree, shrub, and grass cover data, weather data, and pollution concentration monitoring data. Pollution monitoring stations for each study location are pre-determined by the i-Tree Eco system. O_3, NO_2, and $PM_{2.5}$ data are from 2015 from a monitoring station 12.2 km away from the study area; SO_2 data are from 2015 from a monitoring station 58.0 km away from the study area; CO data are from 2015 from a monitoring station 186.7 km away from the study area. Weather data are from 2015, from the Hawarden monitoring station in Flintshire. Details of the pollution removal model calculations are given by Nowak (2020).

Avoided Runoff

i-Tree Eco model calculations of avoided runoff are based on leaf and bark area data and local hourly weather data. I-Tree Eco estimates hourly rain interception, evaporation from leaf surfaces, potential evapotranspiration, transpiration, and surface runoff. Estimates of each process are calculated with the current tree population, and then without trees in order to estimate the impact of trees on surface runoff. Impervious cover beneath trees is held constant at 25.5%. Further details are provided by Nowak (2020).

CTLA

Depreciated Replacement Cost (DRC) methodology is a way of estimating the current cost of replacing an asset (such as a tree) with a modern equivalent, less deductions for physical deterioration, obsolescence, and optimisation (RICS, 2018). DRC is an appropriate valuation method when there is no comparative market-based price that represents the value of the asset, which is the case with trees (RICS, 2018).

In i-Tree Eco, the replacement value of all trees in the study is calculated using the Council of Tree and Landscape Appraisers (CTLA) Trunk Formula Method (TFM). The CTLA is a North American consortium of “green” industry organisations (Cullen, 2007). The TFM is a DRC method commonly used in the United States as a measure of compensatory value, which can be thought of as the cost of replacing trees that have been lost, or the monetary settlement which could be paid to compensate for their damage, death or removal (Nowak et al., 2002).

The Trunk Formula Method (TFM) is suitable for trees that are too large to be replaced like-for-like. The compensatory value is calculated by multiplying a “basic value” by condition and location factors between 0 and 1 (Nowak et al., 2002):

Compensatory Value = Basic Value × Condition factor × Location Factor

The basic value is determined by the replacement cost of a tree at the largest transplantable size, the cross-sectional areas of the stem of the subject tree (TA_A) and of the transplantable tree (TA_R), a basic price, and a species value (Nowak et al., 2002):

Basic Value = Replacement Cost + [Basic Price × ($TA_A - TA_R$) × Species Value]

Replacement Cost, Basic Price and Species Values are derived from the Royal Institute of Chartered Surveyors (RICS), and Barchams and Hilliers catalogues. Species Value takes into account the suitability of the tree species to the local environment.

Condition factors are based on crown dieback recorded during the survey (Nowak et al., 2002):

Crown Dieback	Condition rating	Condition factor
< 1%	Excellent	1
1–10%	Good	0.95
11–25%	Fair	0.82
26–50%	Poor	0.62
51–75%	Critical	0.37
76–99%	Dying	0.13
100%	Dead	0

i-Tree Eco takes a simplified approach to location factor, based on land use type recorded in the survey (Nowak et al., 2002):

Land Use	Location factor
Golf course	0.8
Commercial/Industrial	0.75
Cemetery	0.75
Institutional	0.75
Parks	0.6
Residential	0.6
Transportation	0.5
Forest	0.5
Agriculture	0.4
Vacant	0.2
Wetland	0.1

CAVAT

In addition and separate to the replacement value calculated within i-Tree Eco, we calculate an asset value of Wirral's trees using CAVAT (Capital Asset Value for Amenity Trees). CAVAT is a DRC method developed in the UK (Doick et al., 2018) and is designed for use with urban amenity trees. Only trees in the urban stratum are included in the CAVAT calculation.

Like the CTLA method, CAVAT uses the cross-sectional area of the tree, and a unit value, to arrive at a theoretical cost of a replacement tree, and then decreases or increases that value to account for the individual characteristics of the subject tree. An amended CAVAT Full method is used here:

$$\text{CAVAT value} = \text{Base Value} \times \text{CTI Factor} \times \text{Location factor} \times \text{Crown structural factor} \times \text{Crown functional factor} \times \text{Life Expectancy factor}$$

The Base Value is determined by multiplying the cross-sectional stem area (TA) by the Unit Value Factor[18], which is determined from UK nursery prices and an allowance for tree planting cost:

Base Value = TA × Unit Value Factor

The Community Tree Index (CTI) Factor takes into account the local population density, and appreciates (increases) the value for densely populated areas. For Wirral, this results in multiplication of the Basic Value by 1.25.

Data	Value	Source
Unit value	£16.26	CAVAT documentation
CTI factor	125%	CAVAT documentation
Location factor	Public visibility	i-Tree Eco survey
Crown structural factor	Percent missing	i-Tree Eco survey
Crown functional factor	Percent condition	i-Tree Eco survey
Life Expectancy	Life Expectancy	i-Tree Eco survey

The location factor is based on the public visibility of the tree:

Public visibility	Location factor
Fully visible from at least one direction, on or immediately adjacent to public land	1
Tree clearly visible from a public location, but with somewhat reduced visual contribution to public amenity	0.75
Tree visible from a public location, but with significantly reduced visual contribution to public amenity	0.5
Tree effectively invisible from any public location	0.25

[18] The latest Unit Value Factor can be found on the CAVAT resources webpages at https://www.ltoa.org.uk/resources/cavat.

The crown structural factor is based on the percent of the crown missing, which is recorded during i-Tree Eco surveys:

Percent of crown missing	Crown structural factor
0%	1
1% - 5%	1
5% - 10%	0.9
10% - 15%	0.9
15% - 20%	0.8
20% - 25%	0.8
25% - 30%	0.7
30% - 35%	0.7
35% - 40%	0.6
40% - 45%	0.6
45% - 50%	0.5
50% - 55%	0.5
55% - 60%	0.4
60% - 65%	0.4
65% - 70%	0.3
70% - 75%	0.3
75% - 80%	0.2
80% - 85%	0.2
85% - 90%	0.1
90% - 95%	0.1
95% - 99%	0
100%	0

The crown functional factor is determined by the percentage of the crown in good condition, which is recorded during i-Tree Eco surveys:

Percentage of crown in good condition	Crown functional factor
100%	1
95% - 99%	1
90% - 95%	0.9
85% - 90%	0.9

80% - 85%	0.8
75% - 80%	0.8
70% - 75%	0.7
65% - 70%	0.7
60% - 65%	0.6
55% - 60%	0.6
50% - 55%	0.5
45% - 50%	0.5
40% - 45%	0.4
35% - 40%	0.4
30% - 35%	0.3
25% - 30%	0.3
20% - 25%	0.2
15% - 20%	0.2
10% - 15%	0.1
5% - 10%	0.1
1% - 5%	0
0%	0

The Life Expectancy Factor is determined from the life expectancy of the tree recorded during the survey:

Life Expectancy	Life Expectancy Factor
0 years (dead)	0
<5 years	0.1
5 - <10 years	0.3
10 - <20 years	0.55
20 - <40 years	0.8
40 - <80 years	0.95
=>80 years	1

Details about the full CAVAT method are given in Doick et al. (2018).

Key differences between CTLA and CAVAT

- The CTLA equation uses an actual price of the largest available transplantable replacement tree and adds to this a theoretical cost of the additional cross-sectional area required to reach the size of the subject tree
- CAVAT does not take into account an actual price of a replacement tree, and instead multiplies the cross-sectional stem area of the subject tree by the Unit Value
- Land use and species suitability are considered by this i-Tree Eco version of CTLA and not by the amended CAVAT version
- Population density, crown size, and life expectancy are considered by the amended CAVAT version and not by the i-Tree Eco version of CTLA

Appendix B

Supplementary data

Full species list and importance values

Species	Percentage of total population	Percentage of total leaf area	Importance value
Acer pseudoplatanus	11.5%	17.2%	28.7
Fagus sylvatica	4.7%	11.6%	16.3
Quercus robur	8.6%	6.5%	15.1
Betula pendula	6.1%	5.6%	11.7
Pinus nigra	3.3%	6.6%	9.9
Betula pubescens	5.7%	3.0%	8.7
Pinus sylvestris	4.0%	4.5%	8.5
x Cuprocyparis leylandii	5.8%	2.5%	8.4
Prunus avium	4.4%	2.5%	6.8
Tilia x europaea	0.7%	5.8%	6.5
Fraxinus excelsior	2.6%	2.5%	5.1
Ilex aquifolium	3.4%	1.1%	4.5
Acer platanoides	1.3%	2.4%	3.7
Populus nigra x deltoides	2.7%	1.0%	3.6
Tilia cordata	0.9%	1.9%	2.9
Sorbus aucuparia	2.3%	0.2%	2.6
Quercus	0.9%	1.6%	2.6
Fagus	0.3%	2.2%	2.5
Quercus petraea	1.7%	0.8%	2.5
Salix fragilis	0.6%	1.6%	2.3
Alnus incana	0.8%	1.4%	2.2
Chamaecyparis lawsoniana	1.3%	0.8%	2.1
Betula utilis	0.6%	1.2%	1.8
Salix caprea	1.0%	0.8%	1.7
Picea sitchensis	0.5%	1.2%	1.7
Pinus nigra subsp. laricio	3.3%	6.6%	1.7
Malus	1.3%	0.3%	1.5

Species	Percentage of total population	Percentage of total leaf area	Importance value
Castanea sativa	0.1%	1.3%	1.5
Sorbus intermedia	1.3%	0.2%	1.5
Tilia	0.1%	1.3%	1.4
Betula	1.0%	0.3%	1.3
Crataegus monogyna	1.0%	0.2%	1.3
Prunus domestica	1.0%	0.2%	1.3
Alnus glutinosa	0.5%	0.8%	1.2
Prunus	0.9%	0.2%	1.1
Salix alba	0.5%	0.6%	1.1
Sorbus aria	0.8%	0.3%	1.1
Platanus x hispanica	0.2%	0.8%	0.9
Cordyline australis	0.9%	0.0%	0.9
Cedrus deodara	0.1%	0.8%	0.9
Salix cinerea	0.5%	0.5%	0.9
Quercus rubra	0.3%	0.5%	0.9
Chamaecyparis pisifera	0.7%	0.2%	0.9
Acer palmatum	0.8%	0.1%	0.8
Prunus serrulata	0.6%	0.2%	0.8
Quercus cerris	0.3%	0.5%	0.8
Cupressus	0.6%	0.0%	0.7
Taxus baccata	0.4%	0.2%	0.7
Malus pumila	0.5%	0.1%	0.6
Crataegus	0.5%	0.1%	0.6
Prunus padus	0.5%	0.1%	0.6
Prunus cerasus	0.5%	0.0%	0.5
Laurus	0.1%	0.3%	0.5
Olea	0.4%	0.0%	0.4
Prunus cerasifera	0.3%	0.1%	0.4
Aesculus carnea	0.2%	0.2%	0.4
Acer	0.2%	0.2%	0.4
Ulmus glabra	0.3%	0.1%	0.4
Prunus serrula	0.3%	0.1%	0.4
Photinia x fraseri	0.3%	0.0%	0.3

Species	Percentage of total population	Percentage of total leaf area	Importance value
Magnolia x soulangeana	0.3%	0.0%	0.3
Laburnum anagyroides	0.3%	0.0%	0.3
Alnus	0.3%	0.0%	0.3
Pyrus communis	0.3%	0.0%	0.3
Cupressus sempervirens	0.3%	0.0%	0.3
Sambucus nigra	0.3%	0.0%	0.3
Eucalyptus	0.1%	0.1%	0.3
Fraxinus ornus	0.2%	0.1%	0.3
Eucalyptus globulus	0.1%	0.1%	0.3
Prunus laurocerasus	0.1%	0.1%	0.3
Fraxinus	0.2%	0.0%	0.2
Salix	0.2%	0.0%	0.2
Ilex	0.2%	0.0%	0.2
Syringa vulgaris	0.2%	0.0%	0.2
Corylus avellana	0.2%	0.0%	0.2
Magnolia liliiflora	0.2%	0.0%	0.2
Acer davidii	0.2%	0.0%	0.2
Cotinus coggygria	0.2%	0.0%	0.2
Populus alba	0.1%	0.0%	0.2
Viburnum tinus	0.2%	0.0%	0.2
Salix babylonica var. pekinensis 'Tortuosa'	0.2%	0.0%	0.2
Pinus	0.2%	0.0%	0.2
Prunus spinosa	0.2%	0.0%	0.2
Acer palmatum var. dissectum	0.2%	0.0%	0.2
Juniperus communis	0.2%	0.0%	0.2
Laburnum	0.2%	0.0%	0.2
Juniperus	0.1%	0.0%	0.2
Ulmus	0.2%	0.0%	0.2
Salix viminalis	0.2%	0.0%	0.2
Acer campestre	0.2%	0.0%	0.2
Larix decidua	0.2%	0.0%	0.2
Malus x robusta	0.1%	0.0%	0.1
Eucalyptus gunnii	0.1%	0.0%	0.1

Appendix C

Supplementary information on pests and diseases

Acute oak decline

Acute oak decline (AOD) is caused by multiple agents, especially bacteria. It mainly affects mature trees (>50 years old) of both native oak species (*Quercus robur* and *Q. petraea*), but symptoms have also been identified on younger oaks and additional species, including *Q. cerris* and *Q. fabrei*. Some affected trees can die in as little as 4–6 years after symptoms have developed. Over the past few years, the reported incidents of stem bleeding and exit holes of the associated beetle *Agrilus biguttatus*, indicating potential AOD infection, have been increasing. The condition is most prevalent in a band south of the Mersey, across the Midlands of English from East Anglia to the Welsh Borders. The furthest north verified sites are in Delamere and Mansfield.

Scientists from Forest Research, Cambridge University, and Rothamstead Research undertook a detailed survey for AOD in 2013 and 2014, and combined this with modelling to predict where the disease is likely to take hold. The results show that the Wirral peninsula has a higher-than-average predisposition for acute oak decline. For further information, visit the Forest Research AOD pages.[19]

Asian longhorn beetle

The Asian longhorn beetle (*Anoplophlora glabripennis*) is a major pest in China, Japan and Korea, where it kills many broadleaved species. There are established populations of Asian longhorn beetle (ALB) in parts of North America and there have been outbreaks in Europe. Where the damage to street trees is high, felling, sanitation and quarantine are the only viable management options.

[19] https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/acute-oak-decline/acute-oak-decline-aod-incidence-and-distribution/

In March 2012 an ALB outbreak was found in Maidstone, Kent, England. The Forestry Commission and Fera removed more than 2,000 trees from the area to contain the outbreak. The main risk of another outbreak comes from untreated wood packaging material from China, as in 2012. No further outbreaks have been reported in the UK. Climate suitability modelling suggests that Wirral's climate may be moderately suitable for the survival of the beetle (MacLeod, Evans & Baker, 2002). The known host species include:

- *Acer spp.*
- *Aesculus spp.*
- *Albizia julibrissin*
- *Alnus spp.*
- *Betula spp.*
- *Carpinus spp.*
- *Cercidiphyllum japonicum*
- *Corylus spp.*
- *Fagus spp.*
- *Fraxinus spp.*
- *Koelreuteria paniculata*
- *Malus spp.*
- *Platanus spp.*
- *Populus spp.*
- *Prunus spp.*
- *Pyrus spp.*
- *Robinia pseudoacacia*
- *Salix spp.*
- *Sorbus spp.*
- *Styphnolobium japonicum*
- *Quercus palustris*
- *Quercus rubra*
- *Ulmus spp.*

Bronze birch borer

The Bronze birch borer (*Agrilus anxius*) is a wood-boring beetle that feeds on the inner bark and cambium of birch trees. The disruption to water and nutrient flow that occurs as a result means that trees can die within a few years after symptoms appear. At current, the Bronze birch borer is present across North America, including the United States, where it is native, and Canada. Bronze birch borer has caused extensive mortality of Betula spp. planted as street and ornamental trees in towns and cities, due to its ability to colonize most birch species and cultivars.

Chalara ash dieback

Chalara ash dieback is caused by the fungus *Hymenoscyphus fraxineus.* The fungus reproduces on the leaf stalks of the previous year's fallen leaves. Spores are released in summer and can be spread up to 10 miles on the wind. The fungus penetrates the leaf cuticle and spreads along leaf veins to twigs and branches, where it colonises bark, sapwood, and pith, leading to death of cells (Marciulyniene et al., 2017). The disease is present throughout the UK, and at present there is no management approach that can fully prevent its spread. Figure 46 shows the density and distribution of individual, linear feature, and woodland ash trees in rural areas of Wirral. Wirral has a high density of ash trees in linear features such as hedges and narrow belts of trees, and a relatively low density of ash woodlands. The loss of ash from Wirral's tree population will have a different effect in different places. Planning for eventual replacement of ash trees lost to the disease will help to ensure continued delivery of the benefits they provide.

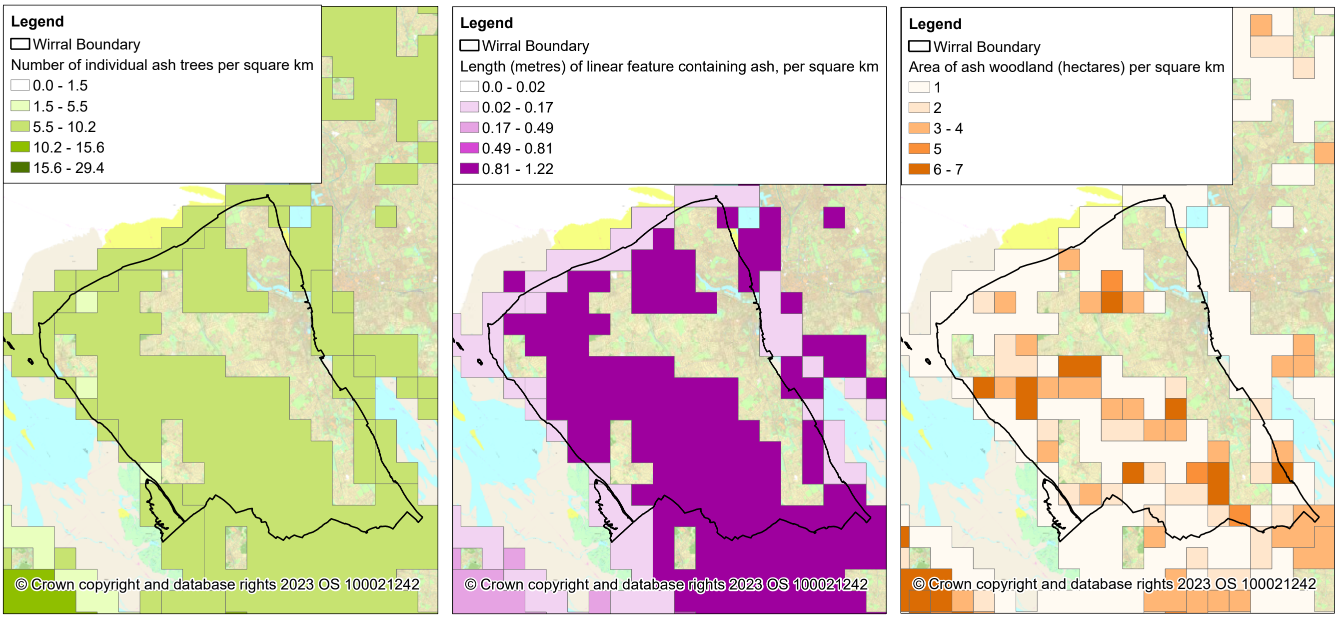


Figure 46. Left: individual ash trees per km^2. Middle: Length of linear woody features containing ash per km^2. Right: Area of ash woodland per km^2. Data source: Maskell et al., 2013a, 2013b, 2013c.

For further information and an interactive distribution map, see Forest Research's resources on Chalara ash dieback.[20]

Citrus longhorn beetle

The citrus longhorn beetle (*Anoplophora chinensis*) is a wood-boring beetle which is extremely damaging to a wide range of broadleaved trees and shrubs in its natural range of China, Japan, the Korean peninsula, and South-East Asia. Beetle larvae feed on the pith and vascular systems of the lower trunk and roots of a tree. The tunnels they create leave the tree susceptible to infections by other organisms.

Beetles have been found around the world in ornamental trees imported from Asia. There have been no outbreaks in the UK but numerous interceptions of individual beetles, mostly associated with *Acer palmatum*. Known hosts include:

- *Acer spp.*
- *Aesculus spp.*
- *Alnus spp.*
- *Betula spp.*
- *Carpinus spp.*
- *Citrus spp.*
- *Corylus spp.*
- *Cotoneaster spp.*
- *Fagus spp.*
- *Malus spp.*
- *Platanus spp.*
- *Populus spp.*
- *Prunus spp.*
- *Pyrus spp.*
- *Salix spp.*
- *Ulmus spp.*

Dothistroma needle blight

Dothistroma needle blight is a disease of conifer trees, especially *Pinus spp.*, caused by the fungus *Dothistroma septosporum.* It is also known as red band needle blight because of the discoloration it causes to foliage, and results in defoliation, reduced growth, and in some cases death of the tree. In the UK it has been found on *P. nigra*, *P. contorta*, *P. sylvestris.*, *P. ponderosa*, and *P. muricata*. Until the 1990s the

[20] https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/ash-dieback-hymenoscyphus-fraxineus/

disease was primarily found in the southern hemisphere. Since then there has been a rapid increase of its incidence in Europe and North America. It is now found in many UK forests containing susceptible species.

Emerald ash borer

Emerald ash borer (EAB) is likely to have a major impact on our already vulnerable ash population in the UK if established. There is no evidence to date that EAB is present in the UK, but the increase in global movement of imported wood and wood packaging heightens the risk of its accidental introduction. EAB is present in Russia and Ukraine and is moving west and south at a rate of 30-40 km per year, perhaps aided by vehicles (Straw et al., 2013). EAB has had a devastating effect in the USA due to its accidental introduction and could add to pressures already imposed on ash trees from diseases such as Chalara dieback of ash.

European mountain ash ringspot associated virus

The European mountain ash ringspot associated virus is a pathogen that attacks the leaves of *Sorbus* trees, causing mottling and discolouration, and in extreme cases increasing the tree's susceptibility to other pests and diseases, reducing the productivity of the tree, and leading to its gradual decline. The main host is *S. aucuparia*, but *S. aria*, *S. torminalis* and *S. domestica* are known to be affected, and the virus has been reported on ornamental *Sorbus* species. It is thought that the virus can move between hosts via grafting wounds and cuttings, and it is unclear whether mites are also involved in the spread of the virus to new hosts. In the UK the virus has only been reported in Scotland, but little is known about its range. In Europe symptoms have been reported in Czechia, Finland, Germany, Poland, Russia, and Sweden.

Horse chestnut bleeding canker

Horse chestnut bleeding canker is a bark disease of *Aesculus spp.*, usually caused by the bacterium *Pseudomonas syringae* pv. *aesculi*. There has been a recent upsurge in incidences in many parts of the UK. IN 2007, 54% of horse chestnut trees in rural areas of north-west England had signs of the disease, and 64% in urban areas (Forestry Commission, 2008). The disease causes bark infections which bleed a dark sticky fluid. It affects trees of all ages and can lead to death, but trees can also have periods of remission and can recover. Horse chestnut trees are also susceptible to leaf miner (*Cameraria ohridella*) and leaf blotch (*Phyllosticta paviae*).

Oak processionary moth

Oak processionary moth (OPM) (*Thaumetopoea processionea*) was accidentally introduced to Britain in 2005 and there are now established OPM populations in most of Greater London and in some surrounding counties. It is thought that OPM has been spread through imported nursery trees. The caterpillars cause serious defoliation of oak trees, their principal host, which can leave them more vulnerable to other stresses. The caterpillars have urticating (irritating) hairs that can cause serious irritation to the skin, eyes and bronchial tubes of humans and animals. They are considered a significant human health problem when populations reach outbreak proportions, such as those in the Netherlands and Belgium in recent years. Whilst the outbreak in London is beyond eradicating, the rest of the UK maintains its European Union Protected Zone status (PZ) and restrictions on moving oak trees are in place to minimise the risk of further spread.

Phytophthora kernoviae

Phytophthora kernoviae is a water mould which can cause disease on the above-ground parts of a wide range of trees, shrubs, and other plants. It causes bleeding cankers on oak and beech tree trunks, and necrosis on the leaves of rhododendrons and magnolias. The winter bark of infected trees produce large quantities of spores which spread the disease, but research suggests that only trees within 5 metres of heavily infected plants (e.g. rhododendron) are at risk, and that infected trees may not be contagious and can recover from infection. Most cases in the UK are located in south-west England, but the disease has also been found in north-west England. Susceptible trees include:

- *Fagus sylvatica*
- *Liliodendron tulipifera*
- *Quercus ilex*
- *Prunus laurocerasus*
- *Ilex aquifolium*
- *Pinus radiata*
- *Magnolia spp.*
- *Rhododendron spp.*
- *Quercus robur*

Pine processionary moth

Caterpillars of the pine processionary moth (*Thaumetopoea pityocampa*) pose a threat to the health of pine trees (*Pinus spp.*) and some other conifer species by feeding on foliage. This can weaken the trees and make them more susceptible to other pests and diseases and to environmental stresses. Like Oak processionary moth, the larvae also pose a hazard to human and animal health. Pine processionary moth is native to southern Europe, North Africa, and parts of the Middle East. Unusually, the larvae of this species hatch in late summer or autumn and feed throughout winter. Local temperature and solar radiation are both important factors when considering climate suitability for this species. Owing to warming winters it has spread north as far as Hungary, Switzerland, and France. It is not known to be present in the UK although occasional single moths and a transient population have been found and eradicated in southern England. The climate of the Wirral is unlikely to be suitable for the larvae but it's northward spread is of concern.

Ramorum disease

Phytophthora ramorum is a water mould, a fungus-like organism that can attack a wide range of trees and other plants. The collective name for the diseases it causes are referred to as Ramorum disease or sudden oak death (note that the genetic forms of *P. ramorum* present in the UK have had little effect on our native oak species *Quercus robur* and *Q. petraea*). For details of symptoms on trees visit Forest Research's Ramorum manual.[21] The disease was first found on a plant in a garden centre in Sussex in 2002, and the first incidence on a mature tree in the UK was in 2003. Ramorum disease has been found in Delamere forest but as yet there have been no reported incidences on the Wirral peninsula. The pathogen can be

[21] https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/ramorum-disease-phytophthora-ramorum/phytophthora-manual-2-identification-and-symptoms-of-ramorum-disease/

spread on footwear, vehicles, tools and machinery, by the movement of infected plants, and in rain, mist and air. It is a particular problem for larch forests. *P. ramorum* affects but is not limited to the following genera and species:

- *Abies alba*
- *A. grandis*
- *A. procera*
- *Acer pseudoplatanus*
- *Aesculus hippcastanum*
- *Betula pendula*
- *Castanea sativa*
- *Chamaecyparis lawsoniana*
- *Fagus sylvatica*
- *Fraxinus excelsior*
- *Ilex aquifolia*
- *Larix spp.*
- *Magnolia spp.*
- *Picea sitchensis*
- *Pseudotsuga menziesii*
- *Quercus cerris*
- *Q. ilex*
- *Q. petraea*
- *Q. robur*
- *Q. rubra*
- *Salix caprea*
- *Sequoia sempervirens*
- *Sorbus aucuparia*
- *Taxus baccata*
- *Tsuga heterophylla*

Red-necked longhorn beetle

The red-necked longhorn beetle (*Aromia bungii*) is a highly damaging pest of trees, particularly in the *Prunus* genus. Larvae tunnel through the bark of trees and into the phloem, interrupting the flow of nutrients. Trees are weakened and become more susceptible to other pests and diseases, and severe infections can result in death. The beetle is thought to be native to China, Korea, Taiwan, and Vietnam. No outbreaks have occurred in the UK, but individuals were found on wooden pallets in a warehouse in 2008, and intercepted.

Its hosts include:

- *Juglans regia*
- *Prunus spp.*
- *Olea europaea*
- *Populus alba*
- *Quercus spp.*

Sooty bark disease of maple

Sooty bark disease of maple is caused by a fungus called *Cryptostroma corticale*, which is thought to have originated in North America. It primarily affects *Acer* species, particularly *A. pseudoplatanus*, *A. campestre*, *A. platanoides*, and *A. negundo*. The fungus enters the tree through wounds, and spores grow in profusion under the bark of the tree or stacked logs, resulting in wilting, dieback, and death. Patches and strips of bark fall off the trunk and exposes thick layers of spores. The spores cause inflammation of the lungs in humans, and great care must be taken when working with infected trees (Braun et al., 2021). The fungus has been found to grow fastest at warmer temperatures and in trees subject to water stress, suggesting that sooty bark disease caused by the fungus is associated with hot, dry summers (Dickenson and Wheeler, 1981; Ogris et al., 2021). The disease was first found in the UK in 1945 and has the potential to become increasingly significant in our changing climate.

Xylella

Xylella fastidiosa is a bacterium that has the potential to cause significant damage or death to a range of broadleaf trees and commercially grown plants. The bacterium has been found in parts of Europe and can be spread through the movement of infected plant material and through insects from the Cicadellidae and Ceropidae families. There are four known subspecies: *Xylella fastidiosa* subsp. *multiplex, Xylella fastidiosa* subsp. *fastidiosa*, *Xylella fastidiosa* subsp. *pauca* and *Xylella fastidiosa* subsp. *Sandyi.* The subspecies *multiplex* is thought to be able to infect the widest variety of trees and plants, including *Quercus robur* and *Platanus occidentalis*. Known hosts include:

- *Acer pseudoplatanus*
- *A. rubrum*
- *Fraxinus angustifolia*
- *Juglans regia*
- *Laurus nobilis*
- *Olea europaea*
- *Platanus occidentalis*
- *Prunus spp.*

- *Quercus robur*
- *Q. rubra*
- *Ulmus glabra*

Pests and diseases resources

Defra plant health portal UK Plant Health Information Portal - UK Plant Health Information Portal (defra.gov.uk)

Defra Plant health risk register UK Plant Health Risk Register (defra.gov.uk)

Forest Research Pest and disease resources pests and diseases resources and advice - Forest Research

TreeCheck About TreeCheck | Department of Agriculture, Environment and Rural Affairs (daera-ni.gov.uk)

Observatree An early warning system for tree health and tree disease - Observatree

TreeAlert TreeAlert - Forest Research

Current and future Climate Matching Tool Climate Matching Tool

Ecological Site Classification tree selection tool Ecological Site Classification (ESC) - Forest Research

The Right Trees for Changing Climate database Right Trees For a Changing Climate (righttrees4cc.org.uk)

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Alice Holt Lodge
Farnham
Surrey, GU10 4LH, UK
Tel: **0300 067 5600**

Northern Research Station
Roslin
Midlothian, EH25 9SY, UK
Tel: **0300 067 5900**

Forest Research in Wales
Environment Centre Wales
Deiniol Road, Bangor
Gwynedd, LL57 2UW, UK
Tel: **0300 067 5774**

info@forestresearch.gov.uk
www.forestresearch.gov.uk

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