Valuing the Natural Capital of Area 1

A pilot study

Please note that the financial values as provided for the tree populations should not be used to derive individual tree values or future projections. i-Tree presents a 'snapshot' in time and many of the calculations are non linear functions, therefore reverse engineering of the figures is not recommended.

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2015 International Year of Soils

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Executive Summary

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

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

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

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

This study was commissioned on behalf of the Highways Agency and provides detailed information on scale of benefits provided by the natural capital of the ‘soft’ estate in Area 1, expressing the economic value of those benefits in monetary terms.

This is the first time that the Highways soft estate has been evaluated in this way in the UK.

Area 1 Headline Figures Baseline Facts		
Total Number of trees	303,000	
Tree cover	34.9%	
Most common species	Ash, Field maple and Sycamore	
Replacement cost (trees)	£91,400,000	
Values		
Pollution removal (trees)	29 tonnes p/yr	£611,000 p/yr
Carbon storage (for trees in year of study (2014))	22,200 tonnes	£1,260,000
Carbon sequestration (trees)	1980 tonnes p/yr	£113,000 p/yr
Avoided Runoff (trees)	75,753.48 cu m p/yr	£40,020 p/yr
Amenity Valuation (trees)	£40,161,044	
Total Annual Benefits	£764,020	
Per hectare Benefits (trees)	£1528.04	
Screening Valuation (trees)	£64,000,000	

Table 1: Headline figures.

Carbon storage: the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation.
Carbon sequestration: the removal of carbon dioxide from the air by plants
Carbon storage and carbon sequestration values are calculated based on DECC figures of £57 per metric ton for 2014
Replacement Cost: value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree)
Pollution removal value is calculated based on the UK social damage costs and the US externality prices where UK figures are not available; £927 per metric ton (carbon monoxide), £6528 per metric ton (ozone), £955 per metric ton (nitrogen dioxide), £1633 per metric ton (sulfur dioxide), £48,517 per metric ton (particulate matter less than 10 microns and greater than 2.5 microns), £48,517 per metric ton (particulate matter less than 2.5 microns)
Screening function is based on the non discounted cost of providing vegetation that has a screening function over a 100 yr period

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"I am the Lorax, I speak for the trees, for the trees have no tongues" – Dr Suess.

Introduction and Background

In the UK, both natural and managed habitats are under pressure. Economic austerity in the course of profound changes in public administration is unlikely to mitigate the pressure on the natural environment. Every penny spent has to count and decisions are expected to be more frequently based on cost benefit analysis.

As the benefits provided by natural capital are not marketable, they are generally undervalued. This may lead to the wrong decisions being made about the natural environment.

Many recent Government documents have highlighted the importance of the range of benefits delivered by healthy functioning natural systems:

- The Lawton Report: Making Space for Nature (2010). This report found that to many of the benefits that derive from nature are not properly valued; and that the value of natural capital is not fully captured in the prices customers pay, in the operations of our markets or in the accounts of government or business.

- UK National Ecosystem Assessment (2011), highlighted that a healthy, properly functioning natural environment is the foundation of sustained growth, bringing benefits to communities, businesses.

- The Natural Choice: Securing the Value of Nature (2011). This white paper set out an integrated approach for creating a resilient ecological network across England, and supporting healthy, well-functioning ecosystems and ecological networks.

- The Natural Capital Committee's third State of Natural Capital (2015) urges government to better protect our natural capital and recommends that corporations begin to take account of these natural assets.

The trees and shrubs on Area 1's soft estate improve the air quality by removing over 29 tonnes of pollutants from the air every year, a service worth at least £ 611 thousand annually.

i-Tree Eco was originally developed as the Urban Forest Effects (UFORE) model in the mid-1990s to assess urban forest impacts on air quality. It has since become the leading urban forest benefits assessment package. It's used in over 100 countries across the globe, helping urban foresters, communities and businesses to manage trees and urban forests effectively.

The Highways Agency own 972 ha of verges, grasslands, shrubs and trees throughout Area 1, which constitutes its 'soft estate'. This is in addition to all its hard or grey infrastructure such as the carriageways access roads and bridges.

The study used existing data, new field work and the i-Tree Eco model (developed by the US Forest Service, and based on peer reviewed research) to quantify the structure of the trees. This was supplemented by a desktop study to evaluate the grassland in order to evaluate some of the major environmental benefits delivered by Area 1's soft estate.

i-Tree Eco was identified as the most complete tool currently available for analysing the trees in Area 1's soft estate. By combining field collected information with local phenological, climate and pollution data it is capable of calculating the function and a range of benefits (or ecosystem services) provided by the soft estate.

i-Tree Eco provides these values at the species level and it is therefore a very useful tool and decision support to help identify, value, manage, and develop strategies concerning the trees present in Area 1.

This report represents the first time that a highways network has evaluated its soft estate in this way.

Fig 1: The Highways Agency network nationwide is split into a number of 'Areas'. Area 1 consists of the A30 and A38 trunk roads to the west of Junction 31 on the M5 near Exeter, and in total contains 289km of trunk road. This report describes the results of a study of Area 1's trees and green infrastructure, carried out in the summer of 2014.

The main objectives of the study were to:

1. Assess the structure, composition and distribution of key elements of the Area 1 soft estate.

2. Quantify some of the benefits of Area 1's trees in order to raise awareness of the natural capital within the soft estate.

3. Establish a baseline from which to monitor trends and future progress.

"Using surveys, drivers from the states of Washington, Minnesota, Michigan, and Maryland were asked to rate scenes containing varied vegetation content and arrangements. Drivers indicated highest preference for roadsides having forest screening, and endorsed agency management in support of roadside nature"

Kathleen Wolf, Green Cities: Good Health – University of Washington

Methodology

To help assess the soft estate in Area 1, data from 72 randomly selected field plots located across the network were analysed using the i-Tree Eco model. i-Tree Eco uses a standardised field collection method outlined in the i-Tree Eco Manual (v 5.0 for this study) (i-Tree 2013), and this was applied to each plot.

This field data, combined with local hourly pollution and meteorological data was submitted to the USDA Forest Service to provide the outputs listed in table 2 below.

Tree Structure and Composition	Species diversity, Tree canopy cover, Age class and Leaf area. Ground cover types. % leaf area by species.
Ecosystem Services	Air pollution removal by urban trees for CO, NO_2, SO_2, O_3 ,PM10 and 2.5. % of total air pollution removed by trees. Current Carbon storage. Carbon sequestered. Stormwater Attenuation and Visual Screening
Structural and Functional values	Structural values in £. Carbon storage value in £. Carbon sequestration value in £. Pollution removal value in £.
Potential insect and disease impacts	Acute Oak Decline *Chalara fraxenia* Emerald Ash Borer Asian Longhorn Beetle Gypsy Moth

Table 2: Study outputs.

Field Survey Data Collected

Plot Information:

Land use type.

Percent tree cover.

Percent shrub cover.

Percent plantable space.

Percent ground cover type.

Tree information:

Species.

Stem diameter.

Total height.

Height to crown base.

Crown width.

Percent foliage missing.

Percent dieback.

Crown light exposure

Due to this being a Highways Agency network, the plots were allocated to management compartments, initially selected according to their pre-existing classification within the Highways Agency Environmental Information System (EnvIS (Design Manual for Roads and Bridges Vol 10 Section 0)).

The EnvIS system applies to every compartment of vegetation and classifies according to both function and type. For the purposes of, and in accordance with EnvIS, the selected functions for this study were; Integration, Screening, and Amenity, and the relevant types being; mature woodland, woodland edge, linear belts of trees and shrubs, shrubs with intermittent trees, high forest, woodland, scattered trees, scrub, and shrubs.

In addition to the fieldwork and in order to obtain a more complete picture of benefits or ecosystem services across the Area 1 soft estate, grassland and soil was also assessed as a desktop study.

Similarly, using the collected field data we carried out an assessment of the amenity value of the trees using the Capital Asset Valuation for Amenity Trees (CAVAT) method.[1]

In total the study area consists of 2250 vegetation compartments covering a total of 972 ha. The field work element for the i-Tree study was concentrated on the 500 ha containing trees, representing 52% of the soft estate within the Area 1 network. The remaining 48% is comprised of grassland, these areas were not included in the fieldwork part of the study.

72 sample plots were randomly assigned across the 'treed' compartments and a 0.04 hectare (ha) plot was randomly located within each compartment selected. This density provided a plot at approximately every 7ha (yielding a relative standard error of ±10%) . In comparison a similar study in Torbay used 242 plots equating to 1 plot every 26 ha.

Data collected included information on land-use, ground-cover types, tree species, tree and shrub measurements, composition, condition, and light exposure (see sidebar).

A full review of the methodology is provided in the scientific paper published by the Forestry Commission, (see Rogers et al 2014).

For a fuller description of the model calculations and field work see Appendix V.

[1] Neilan (2011)

"Anger and frustration may contribute to unsafe driving and may trigger instances of aggressive driving or road rage. Research shows that stress, fatigue from the exercise of directed attention, or a combination of these factors can exacerbate anger and frustration. (…) Roadside vegetation appears to have restorative effects in reducing frustration."

JM Cackowski

Results - The Structural Resource

Ground Cover (within Tree Plots)

Ground cover refers to the types of ground covering, and the EnvIS function, within each plot. For example Herbaceous vegetation includes; ivy, dogs mercury, crops and any other herb level (typically under 25cm tall) plant which is not grass. Mulch is the term given to describe ground coverings of loose organic material such as leaf litter or wood chip. Other ground cover types are self explanatory.

Within Area 1 Herbaceous vegetation layer (63%), Mulched (15%), Grasses (10 %), and Bare soils (7 %) are the most common ground cover types. Low levels of ground cover by water, buildings and other man made surfaces were recorded. This is to be expected given that the survey plots were targeted to the soft estate.

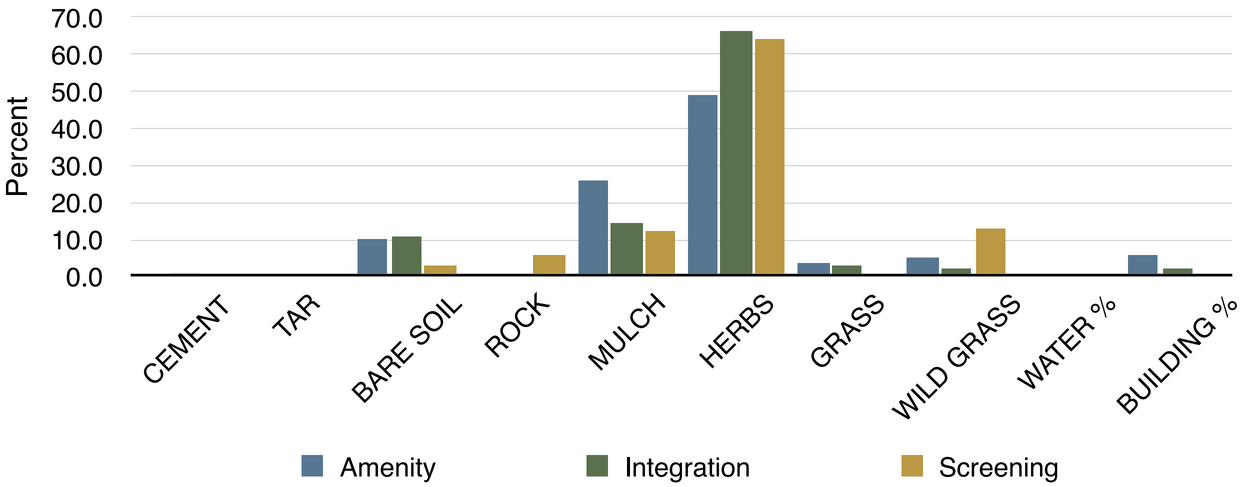

Figure 2 - Ground cover types within tree plots.

Figures for the combined ground cover of the Amenity, Integration and Screening compartments are given below in fig 3.

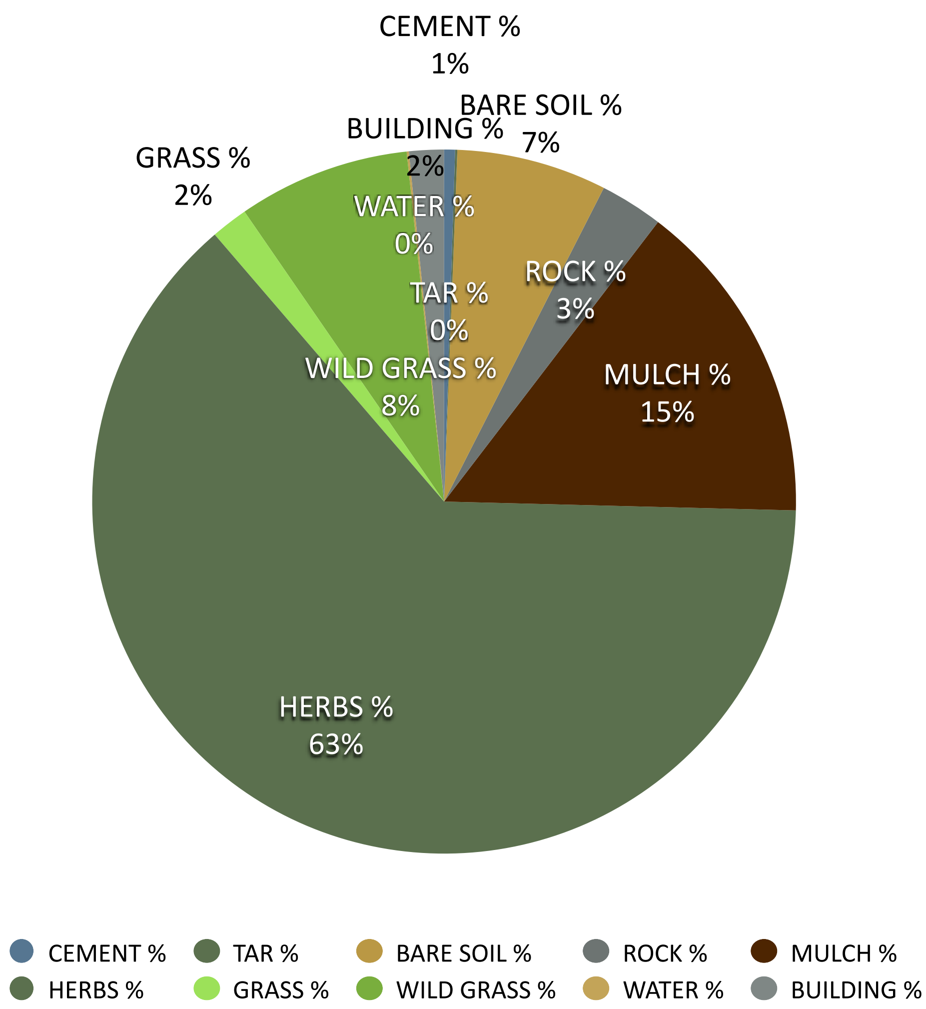

Figure 3 - Ground cover types total.

Of the surveyed area 63% is under tree canopy cover. When the grassland areas are taken into account this equates to 35% percent of the total soft estate within Area 1 being covered by trees.

The survey also showed that a further 8% of land within the tree plots could (in theory) be planted with trees. Utilising available space to increase the tree canopy cover would help reduce pollution and increase carbon sequestration.

Grassland areas (outside the tree plots)

In addition to the tree plots studied with i-Tree Eco there are significant areas of grassland covering 464 ha of the highways network (excluding rock and scree). Just over 50% of the soft estate is classified as grass. Combined with the woodland compartments, the total area of soft estate in Area 1 covers some 972 ha.

It is important to consider these grassland areas, as they too have value and protect the soil, which is also an important carbon sink. Grassland types are provided in table 3 below.

It has been estimated that UK forestry and grasslands sequester 110 ± 4 kg and 240 ± 200 kg of carbon per hectare per year respectively, whereas croplands lose on average 140 ± 100 kg of carbon per hectare per year[2].

Grassland Type	Area (ha)
Swathe	162.5
Conservation / Species rich	61
Open	218.8
Amenity	13
Grass & bulbs	0.4
Heath & moorland	7.8
Total Grass Area	463.5

Table 3: Grassland types within Area 1.

Applying the current UK DECC Carbon figure of £57 per tonne[3] to an average grassland value of 100 kg C/ha equates to £2641 of carbon sequestered every year by the total area of Area 1 grasslands. This is in addition to the 110kg C/ha stored in the forest soils and the amount stored in the trees themselves (discussed later).

However, conclusive values for other ecosystem services provided by grasslands (such as pollution filtration, storm water, habitat and biodiversity) are more difficult to ascertain. Limited studies do exist, yet applying the values to the Area 1 network should be done with caution. A list of comparable studies is given in table 4 below.

It is clear that further research is required to more fully understand and value the ecosystem services provided by grassland.

It is important to consider the other benefits arising from grassland may not yet be fully realised in studies looking at the valuation of ecosystem services. For example, heathland is an important habitat, having seen its distribution decline by 2/3 since the early 1800's[4]. Grassland also has a very important role in adding too and protecting one of the largest carbon sinks (soil).

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[2] Dawson and Smith (2007)

[3] DECC 2011

[4] Handley and Spash 1993, 211.

Grassland	Method	Value	Region	Author
Grassland - Non Agricultural	Estimate and Value Transfer	£230 per ha per year - General Provisioning services	Ontario, Canada	Troy and Bagstad (2009)
	Estimate and Value Transfer	£620 per ha per year - General Provisioning services	Europe	TEEB(2009)
	Green Infrastructure Valuation Toolkit and author estimation	£875 per ha per year Stormwater	Midlands,UK	Holzinger (2011)
Heathland	Green Infrastructure Valuation Toolkit and author estimation	£849 per ha per year Stormwater £0.93 per ha per year Habitat	Midlands, UK	Holzinger (2011)

Table 4 Comparative grassland studies.

Soil

In the UK, as in most regions of the world, the largest terrestrial carbon stock lies below ground in the soil[5]. Every soil possesses a limited carbon storage capacity which is a function of the vegetation type, climate, hydrology, topography and nutrient environment that the soil is exposed to[6].

Soil organic matter has long since been recognised as being vital to the health and beneficial function of landscapes. This organic matter is derived from inputs of leaf, stem and root tissues to the soils that decompose over tens, hundreds and, in the case of peatlands, thousands of years. Soil organic matter provides structural integrity, acts as a source of nutrients for plants, a regulator of hydrology and a habitat for a vast diversity of soil organisms, which in turn drive a range of biogeochemical processes[7].

There have been studies carried out on soil carbon in the UK and carbon storage figures have been calculated for the broad habitat types (see fig 4 and table 5 below).

Applying average values across the Area 1 network provides an estimated value of £33,372 to the grassland soil and £41,000 to the woodland soil for carbon storage. This carbon has been accrued over time and is not an annual benefit. These figures should also be used with caution as there are several assumptions made in the calculations.

Most notably is the fact that these studies are based on soils which, unlike the Area 1 network have not been made up through the construction of the infrastructure. Further work would be needed to provide an accurate figure based on the soil condition at different sites.

[5] Bradley et al., 2005

[6] Gupta and Rao, 1994

[7] Lal 2004

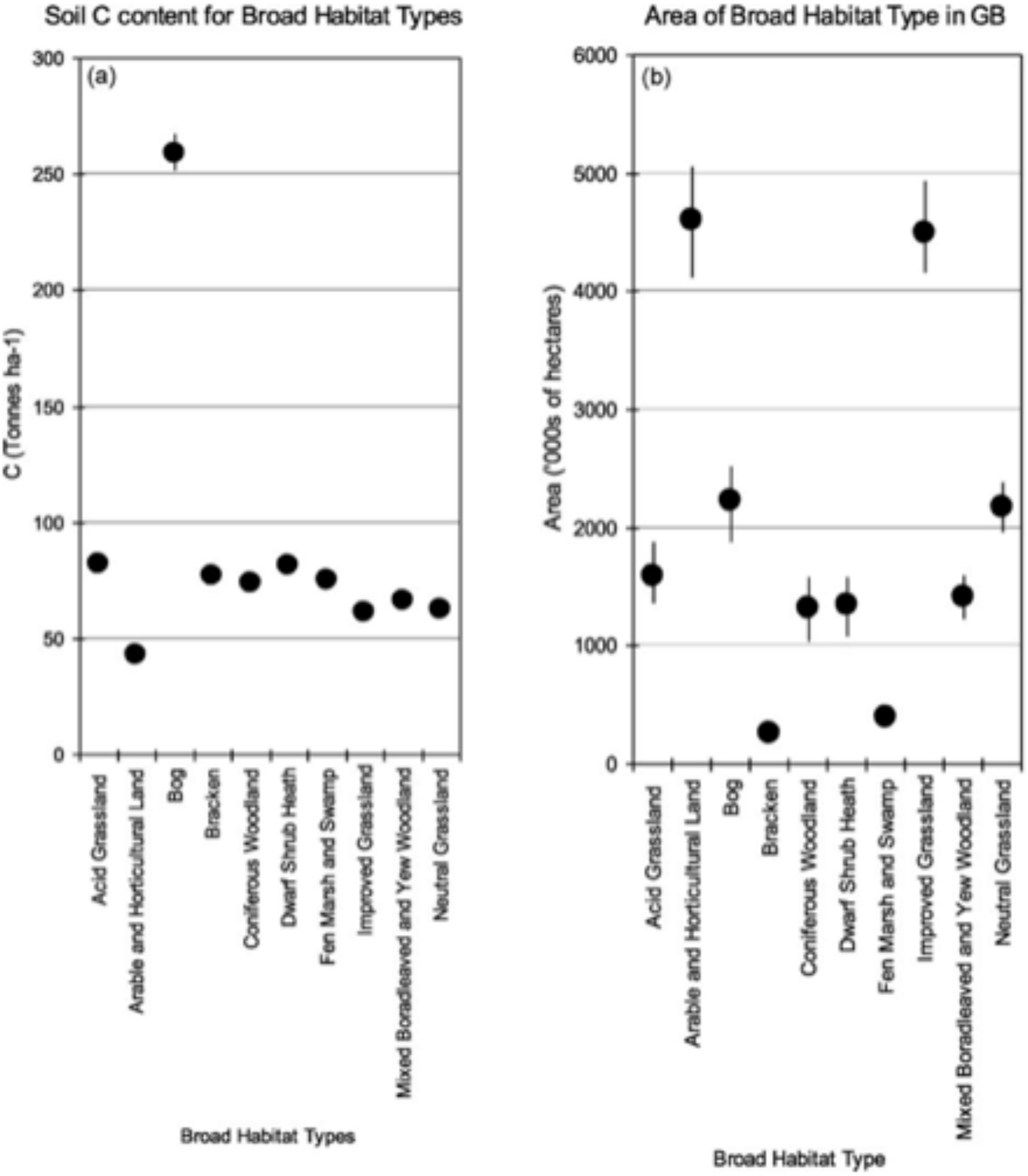


Fig 4. Countryside Survey (2007) Broad Habitat Type and Soil Carbon Data. (a) Mean and upper/lower 95 percent confidence limits of soil carbon content (tonnes hectare) of Broad Habitat Types (BHT) in Great Britain (i.e. excluding Northern Ireland). (b) Mean and upper/lower 95 percent confidence limits of area (in thousands of hectares) of each of the major broad habitat types in GB. Countryside Survey data ©NERC–Centre for Ecology & Hydrology. All rights reserved.

Soil Type	Soil Carbon Storage	Region	Author
Soil under Grassland			
Neutral	62t/ha	UK	Carey et al (2007)
Acid	82t/ha	UK	Carey et al (2007)
Soil under Woodland			
Decidous	66t/ha	UK	Carey et al (2007)
	83t/ha - 119t/ha	UK	Jandl et al (2007)
Coniferous	73t/ha	UK	Carey et al (2007)
Across the board of all land types	1.3 - 70 t/ha	UK	Baritz et al (2010)

Table 5: Soil carbon values.

Tree Cover and Leaf Area

Tree species that contribute the most leaf surface area in Area 1 are:

Ash

Maple

Sycamore

List of the ten most important tree species in Area 1.

Species	I.V.
Ash	37.9
Maple	28.4
Sycamore	24.5
Hawthorn	13.7
Beech	11.9
Wild Cherry	11.7
Goat Willow	11.0
Silver Birch	10.8
Oak (robur)	10.1
Grey Willow	7.2

See appendix III for the full list of tree importance value ranking in Area 1

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

The importance value (IV) is calculated taking into account the leaf area and relative abundance of the species. In Area 1 the most important species in the soft estate are ash, field maple and sycamore, because they contribute the largest leaf areas (fig 5 below).

Tree species such as Silver birch, hawthorn and oak have a much smaller percent of leaf area compared to their percent of population as they are either smaller in stature (hawthorn) or in the case of oak there are simply fewer trees.

A high importance value does not necessarily mean that these trees should be used in the future. Rather, it shows which species are currently delivering the most benefits based on their population and leaf area. These species currently dominate the forest structure and are therefore the most important in delivering benefits

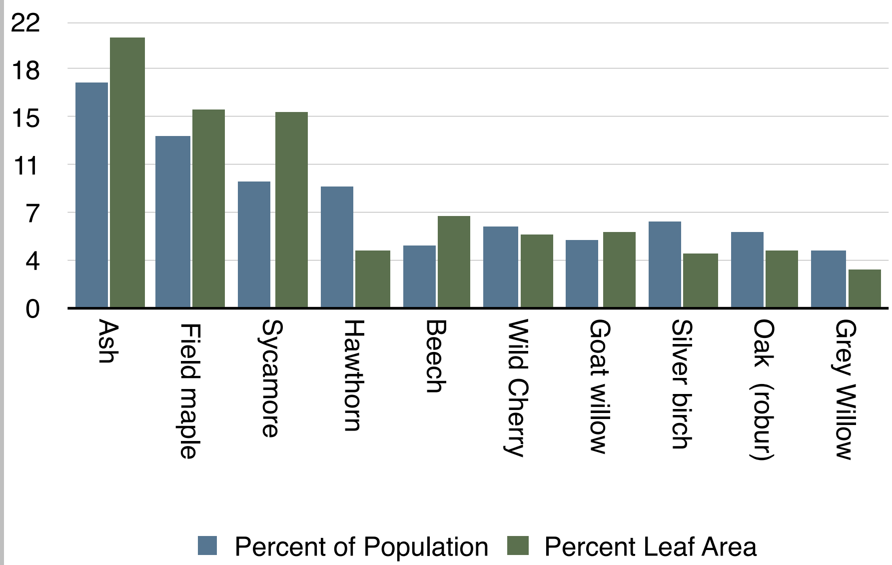


Fig 5: Ten most important tree species in Area 1 by leaf area and population.

Larger trees have a greater functional value and provide increased benefits (details of functional value and the resulting benefits are discussed later). It has been estimated in previous studies[8] that a 75cm diameter tree can intercept 10 times more air pollution, can store up to 90 times more carbon and contributes up to 100 times more leaf area to the tree canopy than a 15 cm tree.

Generally it is the larger trees that contribute more leaf area despite having lower population. Fig 6 (below) illustrates how the leaf area is spread across the different land use functions.

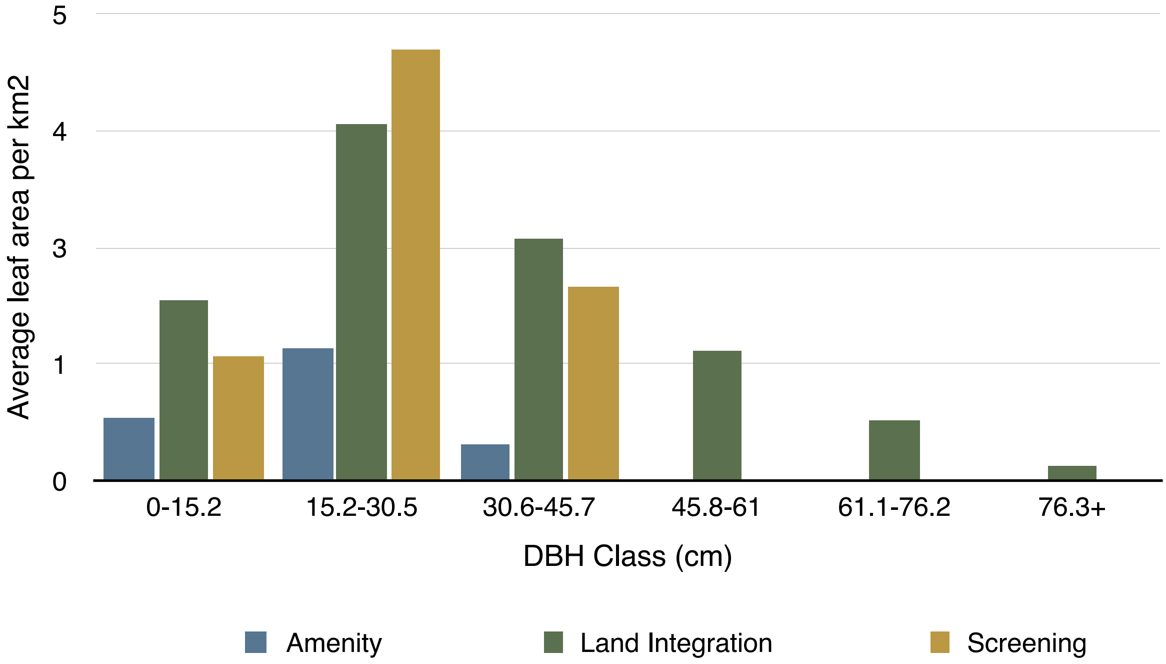


Fig 6: Tree leaf area by DBH.

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

Structure of Area 1's Tree Resource

Area 1 has an estimated tree population of 303,000 trees (606 trees per hectare). Tree cover is an estimated 35% of the total soft estate. Trees with a diameter at breast height less than 15 cm constitute 51.8% percent of the population.

The three most common species are ash (*Fraxinus excelsior*) at 17.2%, field maple (*Acer campestre*) at 13.2%, and sycamore (*Acer pseudoplatanus*) at 9.6% (fig 7below).

The highest tree densities in Area 1 occur in compartments with an Amenity function followed by those with Integration and finally Screening functions.

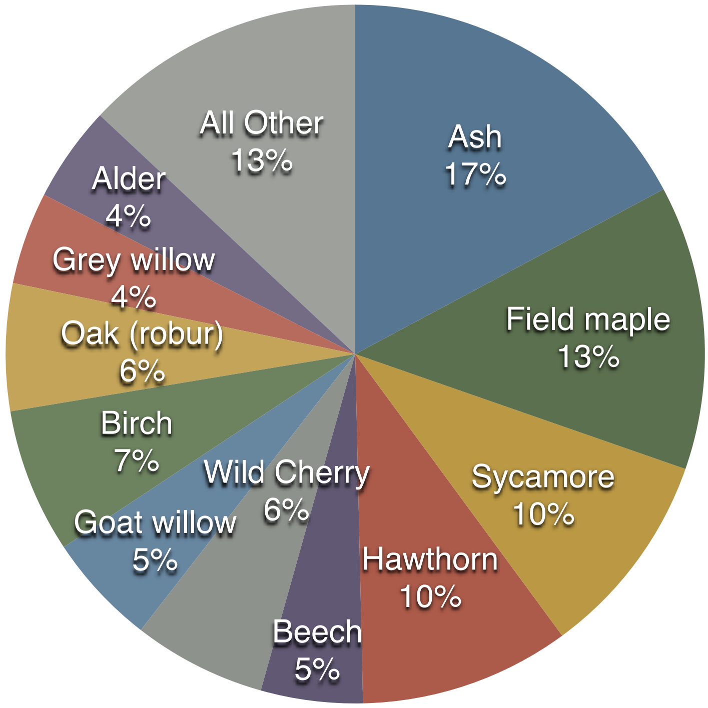


Fig 7: Species composition (most common species).

The ten most common species account for 83% of the total population. In total, 29 tree species were recorded in the survey. As discussed later increased tree diversity has the potential to minimise the impact or destruction of species by specific pathogens and diseases and from climate change.

However, there can be an increased risk to the native tree population by naturalised and exotic species, which can potentially out-compete and displace native species.

Figure 8 (below) shows percentages for each of the four continents from which the 29 species found in the survey originate. More than half (59.9%) of the species are of European origin, and of these, 10.6% are native to Britain.

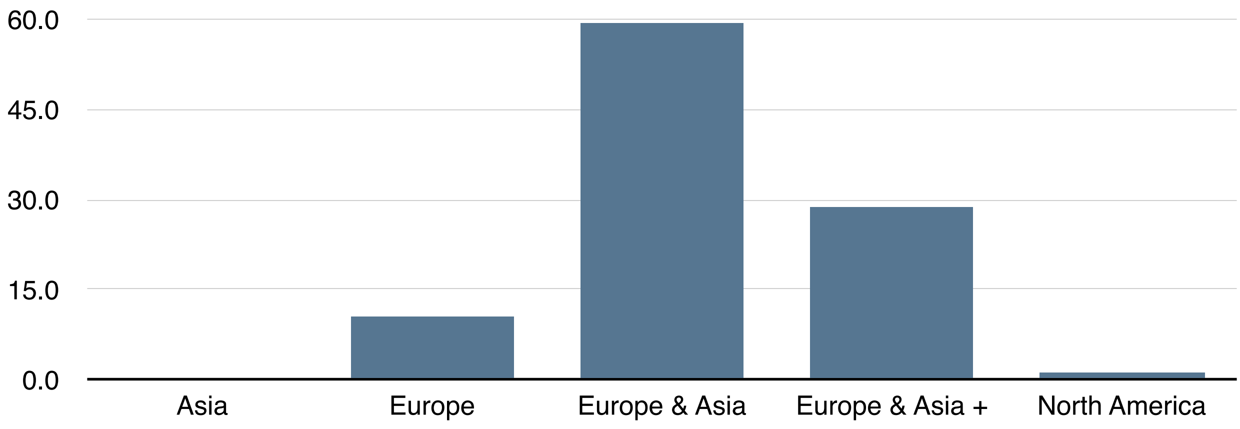


Figure 8. Origin of tree species
Note: The + sign indicates that the species is native to another continent other than the continents listed in the grouping. For example, Europe & Asia + would indicate that the species is native to Europe, Asia, and one other continent.

Size class distribution is also an important factor in managing a sustainable tree population, as this will ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease (fig 9 below).

In this survey trees were sized by their stem diameter at breast height (DBH) at 1.3m. Figure 9 (below) illustrates the size range of trees within Area 1 from their diameters at breast height (dbh).

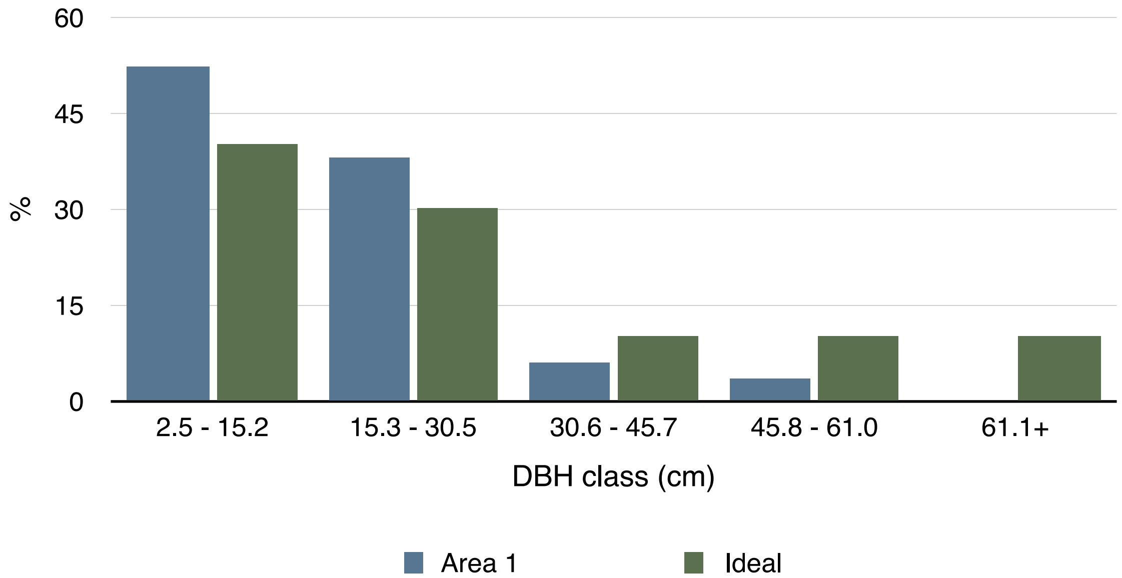


Fig 9. Size class distribution.

Most regions in England only have 10-20% of trees with a dbh that is greater than 30cm (Trees in Towns II). Area 1 also falls within this category.

The majority of trees in Area 1 (57 percent) are in the lowest size category 2.5cm – 15.2cm dbh, which is higher than the 'ideal' target of 40 percent. This reflects the fact that significant parts of the network are relatively young having only been planted in the last 40 years.

This 'ideal' is based on work by the city of Toronto[9] and is intended as a guideline only. Forests are unique and there is no 'one size fits all' target distribution. However, it is noted that Area 1 will benefit from a greater proportion of larger trees as the tree stock matures.

The average dbh of trees in Area 1 is 14cm. 51.8% of the trees have a dbh of less than 15 cm diameter. The data shows that only 10% of trees in Area 1 have a d.b.h. greater than 30.6cm.

The percentage of trees within each dbh class decrease with increasing diameter class and as a result the percentage of medium and large trees is lower than the ideal scenario illustrated in fig 9.

Area 1 has a relatively dense tree population at 606 trees per ha. For comparison, i-Tree Eco studies undertaken in Torbay and Edinburgh had respective densities of 128 and 56 trees per ha. However it must be noted that in due course this density will decrease in Area 1, as thinning operations are carried out. However, overall biomass and associated tree benefits should continue to rise as the remaining trees attain a larger size.

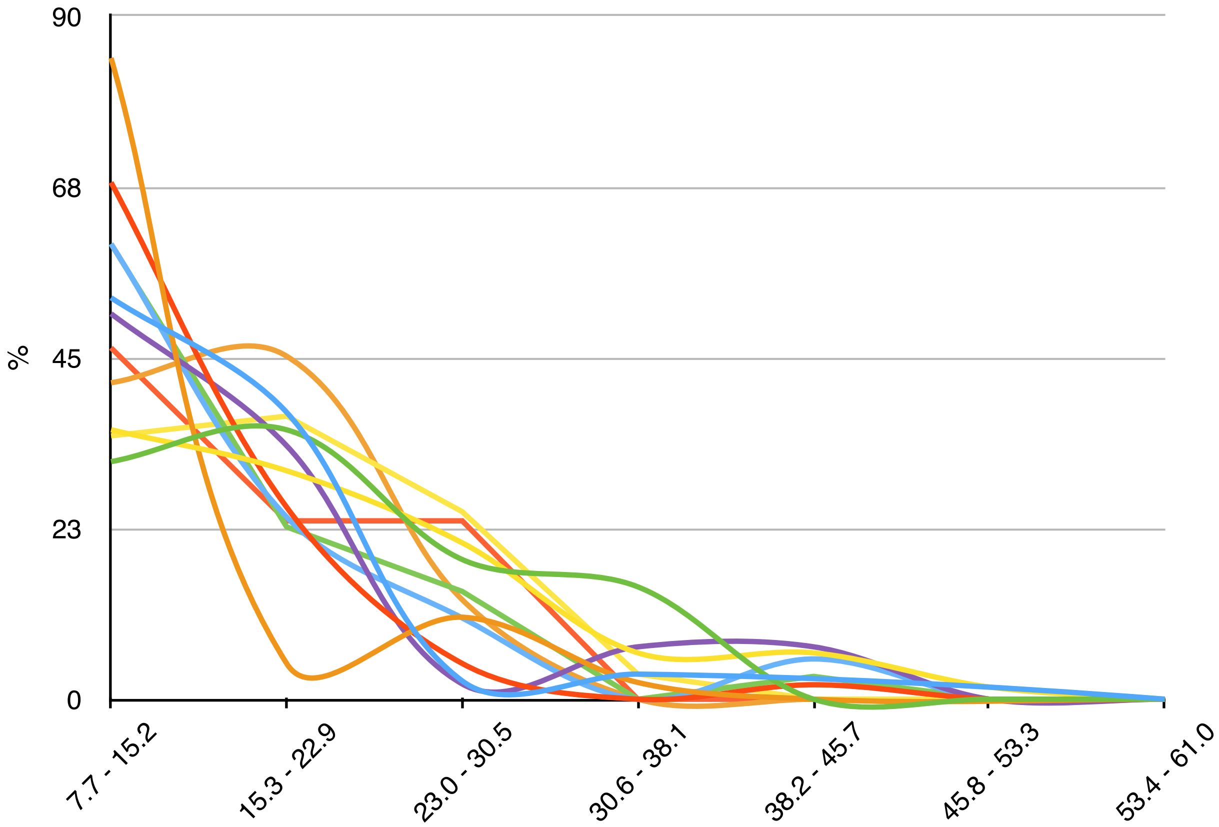


Fig 10: Percentage DBH Class by most significant species.

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

Results - Ecosystem Services Resource

Air Pollution Removal and Area 1 Trees

Area 1's trees and shrubs remove particulate matter (PM10's) equivalent to the annual emissions from 31,000 large family cars.

In the United Kingdom the government estimate that at least 24,000 people die each year as a result of air pollution. (NUFU, 1999).

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

The problems caused by poor air quality are well known, ranging from human health impacts to damage to buildings.

Trees make a significant contribution to improving air quality by reducing air temperature (thereby lowering ozone levels), directly removing pollutants from the air, absorbing them through the leaf surfaces and by intercepting particulate matter (eg: smoke, pollen, ash and dusts). They also indirectly reduce energy consumption in buildings, leading to lower air pollutant emissions from power plants.

Pollutant	Tonnes removed per year	Value
Carbon monoxide (CO)	0.00035	£ 0.33 (UKSDC)
Nitrogen dioxide (NO_2)	3.32	£ 3172 (UKSDC)
Ozone (O_3)	14.56	£ 95,041 (USEC)
Particulates PM10's	10.5	£ 511,691.00 (UKSDC)
Particulates PM2.5's	0.029	£1392.00 (USEC)
Sulphur dioxide (SO_2)	trace	£0.00

Table 6: Value of the pollutants removed and quantity per-annum within Area 1. Valuation method's used are UK social damage cost (UKSDC) where they are available - where there are no UK figures, the US externality cost (USEC) is used as a substitution.

As well as reducing ozone levels, it is well known that a number of tree species also produce the volatile organic compounds (VOCs) that lead to ozone production in the atmosphere. The i-Tree software accounts for both reduction and production of VOCs within its algorithms, and the overall effect of Area 1's trees is to reduce ozone through evaporative cooling.[10]

10 Nowak et al, 2000.

A study in the West Midlands suggests that doubling tree cover across the region would reduce the concentration of fine PM10 particles by 25%. This could prevent 140 air pollution related premature deaths in the region every year. Stewart H, et al (2003).

Total pollution removal per ha in Area 1 is 0.03t ha^{-1} yr^{-1}. These values are higher than have been recorded by other studies 0.009t ha^{-1} yr^{-1} for a site in London[11] (PM_{10} only) and .023t ha^{-1} yr^{-1} for a site in Guangzhou, China[12]. This is probably due to the greater canopy cover area on the highway network which will result in more pollutants being removed.

Greater tree cover, pollution concentrations and leaf area are the main factors influencing pollution filtration and therefore increasing areas of tree planting have been shown to make further improvements to air quality[13]. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits.

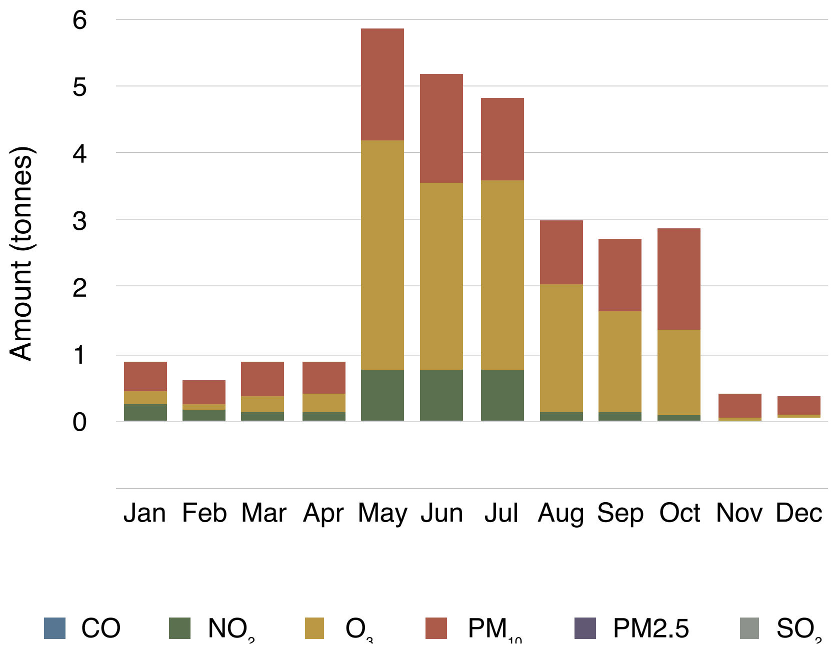


Fig: 11 Monthly pollution removal.

Pollution removal by trees in Area 1 is highest in the summer months (see fig 11 above). There is also greater leaf surface area during this period and therefore greater stomatal activity due to the increased day-light hours. It's worth noting that generally, pollution levels are also higher during this period of the year due to increased traffic volumes using the main (A30) entry route into the region. Tourism is one of the main industries in the South West and the population effectively doubles during the summer months.

11 Tiwary et al (2009)

12 Jim and Chen (2008)

13 Escobedo and Nowak (2009)

Pollution removal was greatest for ozone. It is estimated that trees and shrubs remove 29 metric tons of air pollution ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) particulate matter less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), and sulphur dioxide (SO_2) per year with an associated value of over £ 611,000 (based on estimated mean externality costs associated with pollutants and UK social damage costs published by DEFRA)[14]. The annual values for this pollution removal are given in table 13 (below). $PM_{12.5_0}$

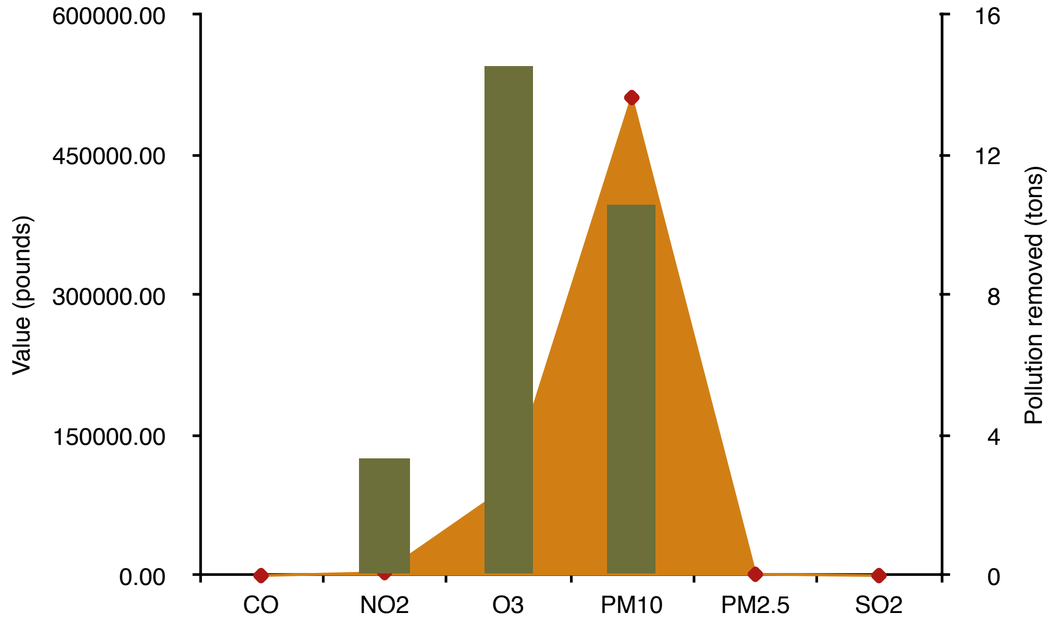


Fig 12. Annual Pollution Removal and Associated Value.

Road Transport Forecast

Forecasts from the Department for Transport's National Transport Model (DoT 2013) up to 2040 predict that for the Strategic Road Network (SRN) from 2010 – 2040 traffic growth will be 46%.

This figure is subject to several key variables such as the price of oil and potential impacts will vary according to factors such as the take up of ultra –low emission vehicles such as electric cars.

It is also forecast that the levels of CO_2 will decline up to 2030 before slowly starting to rise again due to increased demand. This would imply a 15% reduction on 2010 CO_2 levels by 2040. Similarly road transport No_x and PM_{10} emissions from 2010 – 2040 are forecast to fall by 62% and 93% respectively with most of the reduction occurring before 2025.

Whilst the above predictions are positive in terms of pollution levels, this has to be put into context in that only a proportion of pollutants are absorbed at present and even if the predictions are correct vehicles using the network will still overall be a significant net producer of pollutants.

14 DECC (2011)

Carbon Storage and Sequestration

Carbon storage:

Carbon currently held in trees tissue (roots, stem, and branches).

Carbon sequestration:

Estimated amount of carbon removed annually by trees: Net carbon sequestration can be negative if emission of carbon from decomposition is greater than amount sequestered by healthy trees

Trees can help mitigate climate change by sequestering atmospheric carbon as part of the carbon cycle. Since about 50% of wood by dry weight is comprised of carbon, tree stems and roots can store up carbon for decades or even centuries[15]. Over the lifetime of a tree, several tons of atmospheric carbon dioxide can be absorbed[16].

An estimated 22,200 tonnes (approximately 22.8 t/ha) of carbon is stored in Area 1's trees with an estimated value of 1.26 million pounds (based on current carbon figures from DECC)[17].

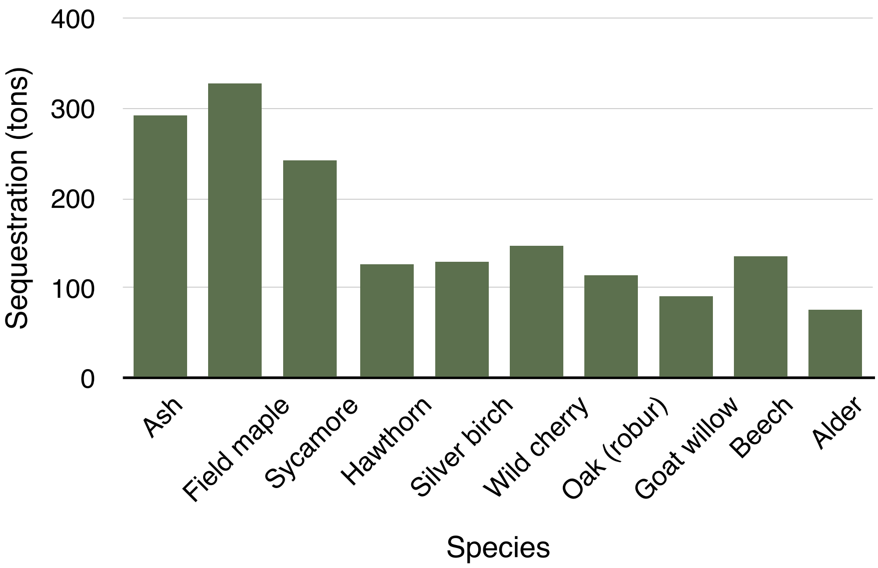


Fig 13: Ten most significant tree species for carbon sequestration currently in Area 1.

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

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

15 Kuhns, 2008

16 McPherson, 2007

17 DECC (2011)

Large trees are particularly important carbon stores and new plantings such as these, which have also been adequately protected from mower damage will help to ensure that current levels are maintained.

The gross sequestration of Area 1's trees is about 1,980 tonnes of carbon per year (approximately 2t/yr/ha). The value of the carbon sequestered is estimated at £113,000 per year. This value will increase in a sigmoidal fashion as the trees grow.

Ash, field maple and sycamore are currently the most important trees in Area 1 in terms of carbon sequestration. Field maple hold approximately 17.8% of the total carbon stored (see fig 13 above)

Area 1 has a large proportion of smaller (both in age and ultimate size potential) trees and carbon sequestration from small trees is minimal. However, a proportion of these trees will grow thus offsetting the decomposition from tree mortality.

Trees also play an important role in protecting soils, which is one of the largest terrestrial sinks of carbon. Soils are an extremely important reservoir in the carbon cycle because they contain more carbon than the atmosphere and plants combined (Ostle et al 2011).

Table 7 (below) provides a breakdown of carbon stored and sequestered across the land use functions. The greatest amount of carbon is stored in the Screening category and the least in the Amenity category. This is despite the fact that the greatest tree density occurs in the Amenity areas. This reflects the smaller stature of trees found within the Amenity compartments (see fig 6).

Landuse	Carbon Storage (tonnes)	Percent	Carbon Sequestered (tonnes)	Carbon Storage (kg/ha)
Amenity	2,619.22	11.8%	293.33	45,711
Land Integration	9,100.61	41.1%	803.47	49,379
Screening	10,449.6	47.1%	887.87	45,256

Table 7. Comparison of carbon stored and sequestered by land use function.

Stormwater Run-Off

Surface runoff can be a cause for concern in many areas as it can contribute to pollution in streams, wetlands, rivers, lakes, and oceans.

During precipitation events, a portion of the precipitation is intercepted by vegetation (trees and shrubs) while a further portion reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff[18].

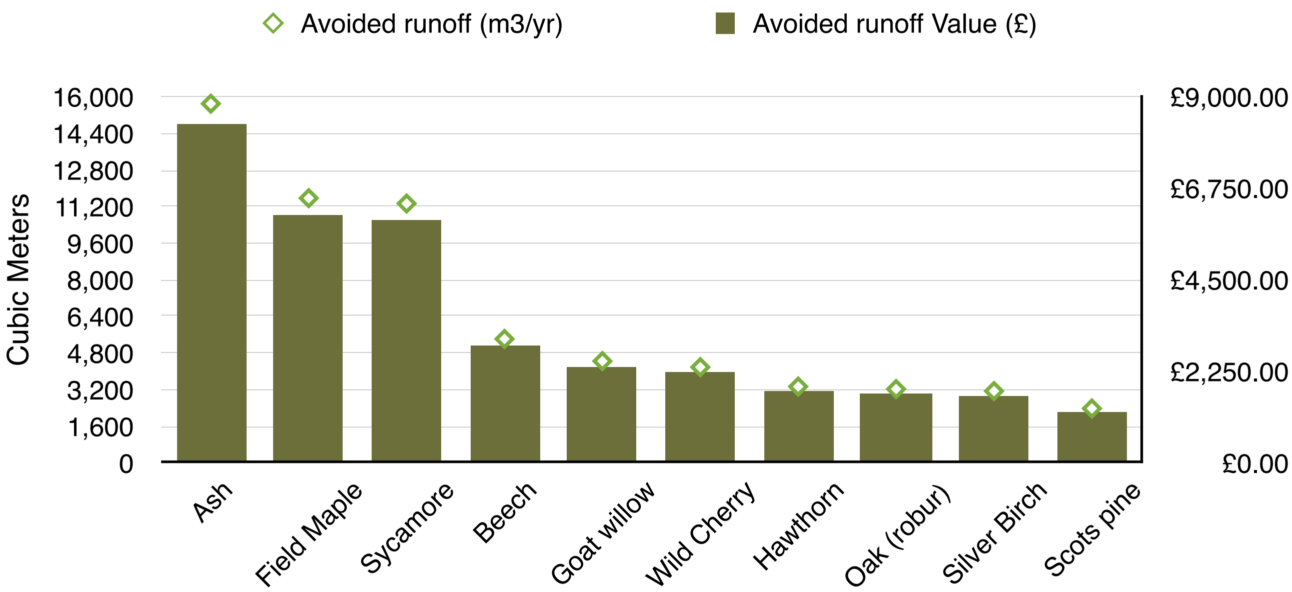
Within a highways network, the large extent of impervious surfaces increases the amount of runoff. However, trees are very effective at reducing surface runoff[19]. Trees intercept precipitation, while their root systems promote infiltration and storage in the soil.

The trees of Area 1 help to reduce runoff by an estimated 75,753 cubic meters a year with an associated value of £40,020.00.[20] Table 8 (below) provides the comparison between each landscape function.

Ash intercepts the most water, removing 15 691 m3 of water per year, a service worth £8289 (Fig 14). This is due to its population and canopy size.

Land Use	Tree Number	Leaf Area (km2)	Avoided Runoff (m3/yr)	Avoided Runoff Value (£)
Amenity	50806	2.4	10,041	5,304.44
Land Integration	122867	7.51	31,388	16,582.16
Screening	129561	8.22	34,325	18,133.97
Totals	303234	18.13	75,753.48	40,020.57

Table 8 (above): Comparative values for avoided runoff buy each land function type.
Fig14 (below) avoided runoff top ten species.



[18] Hirabayashi (2012).

[19] Trees in Hard Landscapes (2014)

[20] Calculated using US externality of £0.528/m3

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

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

Replacement Cost

In addition to estimating the environmental benefits provided by trees the i-Tree Eco model also provides a structural valuation which in the UK is termed the 'Replacement Cost'. It must be stressed that the way in which this value is calculated means that it does not constitute a benefit provided by the trees. The valuation is a depreciated replacement cost, based on the Council of Tree and Landscape Appraisers (CTLA) formulae (Hollis, 2007).

The formula allows for tree suitability in the landscape and nursery prices. This explains why the value given for field maple is more than that reported for ash, on account of its decreased suitability due to *Chalara fraxinea* a pathogen discussed below.

Replacement Cost is intended to provide a useful management tool, as it is able to value what it might cost to replace any or all of the trees (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The replacement costs for the ten most valuable tree species are shown in figure 15 below.

The total value of all trees in the study area currently stands at £ 91.4 million. Field maple is the most valuable species of tree, on account of both its size and population, followed by ash and sycamore. These three species of tree account for £ 44.2 million (48%) of the total replacement cost of the trees in Area 1.

A full list of trees with the associated replacement cost is given in appendix III

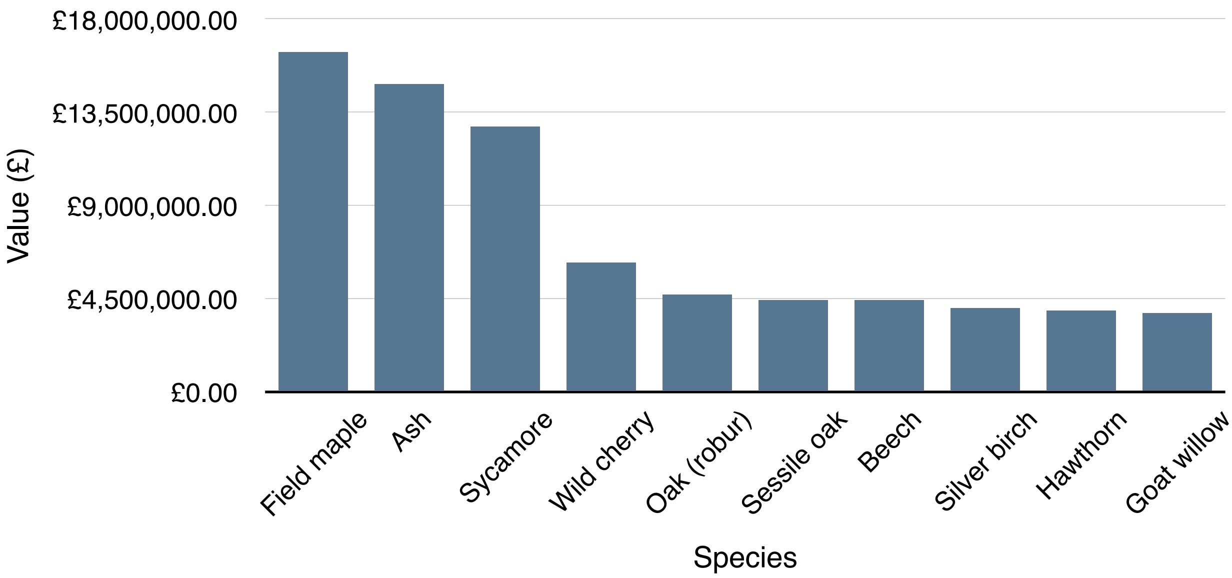


Fig 15: Replacement Cost of the 10 most valuable tree species in Area 1.

CAVAT - The amenity value of Area 1's trees

Capital Asset Valuation for Amenity Trees (CAVAT) is a method developed in the UK to provide a value for the public amenity that trees provide, rather than the property approach taken in the CTLA method. The two methods are often confused but are in fact addressing two different aspects of Area 1's trees.

Whilst CTLA provides a replacement cost for management purposes, CAVAT includes the addition of the Community Tree Index (CTI) factor, which adjusts the CAVAT value to take account of the greater amenity benefits of trees in areas of higher population density, using official population figures. This adds a further social dimension to Area 1's trees, placing a value on the trees visual accessibility and prominence in the landscape.

Area 1's trees are estimated to be worth £40 million according to the CAVAT assessment, which takes into account the health of trees, their accessibility and prominence in the landscape. The ash hold the highest value (Fig 16 below), representing 23% of the value of all the trees. The single most valuable tree encountered in the study was also an ash, estimated to have an asset value of £5431.00.

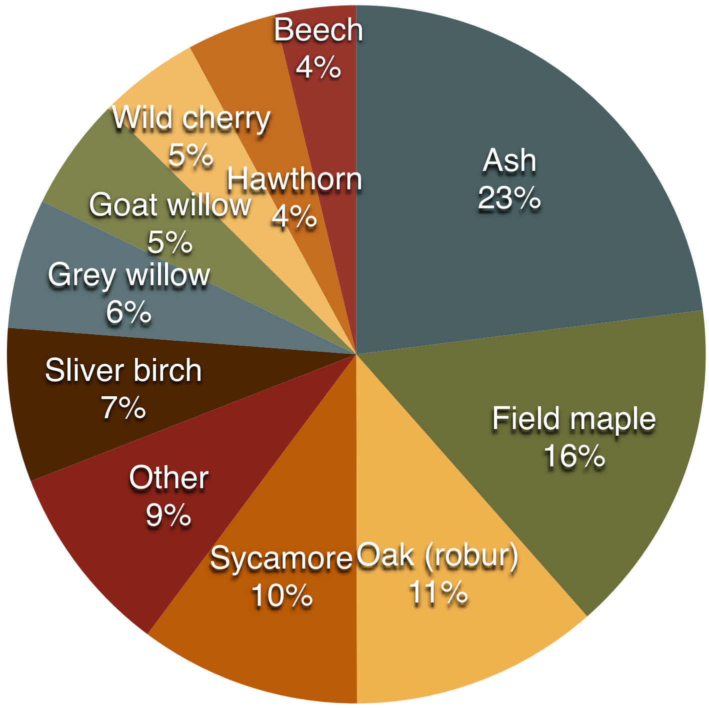


Fig 16: Percentage of CAVAT value by species.

There are good populations of native tree species in the Area 1 network. These species are important for biodiversity and the ecology of the landscape.

However, the population of other non natives will become increasingly important in a changing climate. as the range of native species is effected.

Tree Diversity

Challenges exist in valuing biodiversity because it is difficult to identify and measure the passive, non-use values of biodiversity[21]. However, biodiversity is important because it provides a wide range of indirect benefits to humans.

Although i-Tree Eco does not yet calculate a valuation of biodiversity it does provide an indication of tree species diversity using diversity indexes (Shannon, Simpson and Menhinick methods). This is important because the diversity of species within the Area 1 soft estate (both native and non-native) will influence how resilient the tree population will be to future changes, such as minimising the overall impact of exotic pests, diseases and climate change. These values are provided in table 9 (below).

Species	Species/ha	SHANNON	MENHINICK	SIMPSON	EVENNESS
31	4.4	2.63	1.32	10.43	0.78

Species	Species/ha	SHANNON	MENHINICK	SIMPSON	EVENNESS
102	10.46	3.32	2.96	15.31	0.72

Table 9: Species richness and diversity Indexes for Area 1 (grey - top) with details of an Urban Forest (green - bottom).

Spp: is the number of species sampled.

SPP/ha: is the number of species found per hectare of area sampled.

SHANNON: is the Shannon – Wiener diversity index, which assumes that all species within the area have been sampled. It is an indicator of species richness and has a moderate sensitivity to sample size.

MENHINICK: is the Menhinick's index. It is an indicator of species richness and has a low sensitivity to sample size and therefore may be more appropriate for comparison between cities.

SIMPSON: is Simpon's diversity index. It is an indicator of species dominance and has a low sensitivity to sample size and therefore may be more appropriate for comparisons between land-use types.

EVENNESS: is the Shannon diversity index, which assumes that all species within the area have been sampled. It is an indicator of species evenness and has a moderate sensitivity to sample size and therefore land-use and/or cities may not be comparable.

21 Nunes et al, 2001

Many native species are not able to thrive in the artificial environments of our landscaped areas, and the effects of climate change will exacerbate the situation[22]. For example; the range of Beech is predicted to contract from its current range to more northern reaches of Britain and many other broadleaf and conifer species will also be affected[23], whereas non-native species, could become increasingly important for the delivery of benefits in Area 1.

Species selection is an important consideration because there is also potential for some exotics to out-compete and displace native species and reduce native species habitat.

31 species were sampled in Area 1 equating to approximately 4.4 species p/ha with a calculated Shannon diversity index of 2.63 (On this scale 1.5 is considered low and 3.5 is high). This result represents a fairly diverse tree-scape, which one might hope will be more resilient than that represented by one which is more homogenous.

Most of the tree diversity is focused in the Integration compartments followed by the Amenity and Screening areas. The diversity for each land-use function is compared in table 10 below.

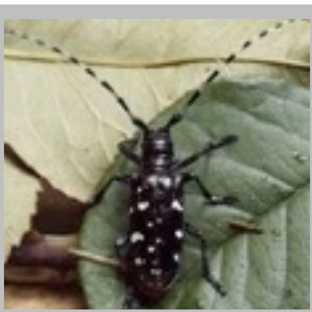
Landuse	Species	Species/ha	SHANNON	MENHINICK	SIMPSON	EVENNESS
Amenity	16	10.7	2.36	1.40	9.09	0.85
Land Integration	24	6.2	2.49	1.50	8.63	0.78
Screening	15	8.3	2.47	1.54	11.45	0.91
Total	31	4.4	2.63	1.32	10.43	0.78

Table 10: Tree diversity by landscape function.

22 Gill et al 2007

23 Broadmeadow et al 2005

Threats



Asian longhorn beetle

Ⓒ Forestry Commission

In an analysis of 18 years data, researchers found that Americans living in areas infested by emerald ash borer suffered an additional 15,000 deaths from cardiovascular disease and 6,000 more deaths from lower respiratory disease when compared to uninfected areas.

Potential Pest and Disease Impacts

The potential impact of pests and diseases may vary according to a wide variety of factors such as tree health, local tree management, and the weather. In addition, pests and diseases often occur most frequently within a particular tree family, genus or species.

A tree population that is dominated by a few species is therefore more vulnerable to a significant impact from a particular disease than a population which has a wider variety of tree species present.

In relation to Area 1, the tree stock is dominated by species such as: ash, field maple, sycamore and oak. As a result, the potential impact of five pests that may affect those species was analysed in relation to potential damage.

Fig 17 (below) illustrates the percentage species susceptibility to these identified threats. Fig 18 (below) illustrates the potential cost of an outbreak by the pathogens investigated.

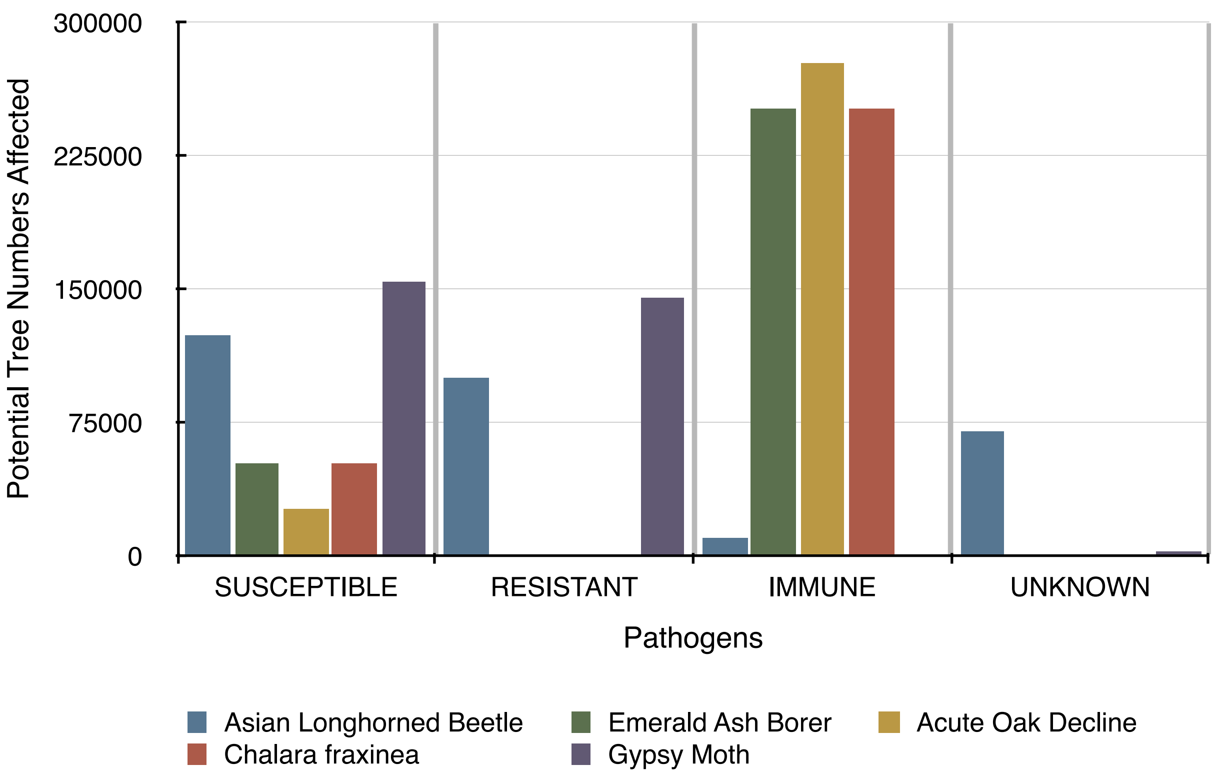


Figure 17: Potential number of trees that could be affected by pathogens.

Asian Longhorn Beetle

Asian Longhorn Beetle is a native of SE Asia where it is a major problem and kills a variety of hardwood species such as those found on the Area 1 network. The beetle has established within, and was found to have entered the USA within wood used for packaging.

It is likely that beetles entering the UK would also arrive by the same means. To date the beetle has been found in the UK during inspections of incoming packaging in several ports, and a small population established in Kent in 2012 (and once located was removed by the Forestry Commission and the Food and Environment Research Agency).

It is estimated by the United States Department of Agriculture Forest Service[24] that unless the spread of the beetle is contained, the beetle could result in up to 30% tree mortality across the United States.

As the more dominant families of trees contained within Area 1 are preferential for the beetle it is possible that an outbreak with the current tree species make-up could affect 41.8 % of the tree population. This would present a potential loss to the tree stock in Area 1 of £ 41 million.

Emerald Ash Borer

A native of Asia, again it is thought that the beetle has been in introduced to new countries in imported packaging material. It has caused the deaths of millions of ash trees in the United States, and once established containment has proved difficult.

Ash is the most common species within the Area 1 network (17.3%), and EAB has the potential to cause a loss of trees that would cost to £15.3 million to replace. The potential impact upon the Area 1 tree stock if EAB became established could be significant because of the high proportion of ash present.

Acute Oak Decline

There have been episodes of 'oak decline' documented for almost 100 years, and it is regarded as a complex disorder whereby typically several damaging agents interact. The outcome often results in high levels of mortality, but trees can sometimes also recover. Two key types of decline have been identified: Chronic Oak Decline (COD) – decline tends to be slow (10 – 50 years) and the focus is often on roots, and Acute Oak Decline (AOD) where decline tends to be fast (2 – 5 years) and the focus is on above ground parts.

The distinction between the two is often based on rate of decline and both can occur together or one lead to the other. Conditions that make oak trees susceptible to AOD are not yet known or researched in Britain but maybe triggered by:

- Cycles of foliage destruction (often caused by defoliating insects and powdery mildew) which weaken the tree.

- Damage to bark cambium where phloem and cambium are destroyed (probably caused by insects and bacteria).

This most recent episode of AOD has to date occurred predominantly in the SE and Midlands. Its distribution in the UK over recent years has however slowly intensified and spread to include Wales, East Anglia with occasional occurrences in the SW.

[24] www.na.fs.fed.us/pubs/palerts/alb/alb_pa.pdf

Once the disease has occurred, generally the infected trees are retained unless there is an imminent concern regarding safety. Due to the close proximity of a high value target i.e. the carriageway within Area 1, removals may therefore be necessary. Alternatively, if limited numbers of trees appear infected then it may be prudent to fell and destroy infected individuals to reduce infection levels and reduce the risk of the disease spreading.

If the occurrence of this disease increases in the SW, the presence of this disease represents a potential loss to the tree stock in Area 1 of £ 9.66 million representing 8.3% of the tree population.

Chalara fraxinea

Chalara is a vascular wilt fungus which causes the dieback and death of ash trees and whilst thought to have introduced to Europe in 1992, it was first discovered in the UK in a nursery in Norfolk in 2012.

It has had a major impact upon the ash population in several countries e.g. Denmark, and since being found in the UK the rate of infection has increased at a steady rate and has now been found in over 900 locations, especially in the South East [25]. Whilst initially occurring predominantly in ash populations that had been recently planted, by the summer of 2014 infected trees were being mainly found within established trees in the wider environment.

As with EAB, Chalara could pose a significant threat to the delivery of tree benefits in Area 1.

Gypsy Moth

Gypsy Moth is a serious pest causing significant defoliation to oak trees, but also species such as hornbeam, beech, chestnut, birch and poplar[26]. In addition, the moth has urticating hairs, which can cause severe allergic reactions. It has been present within Britain in North East London since 1995, and since then it has also been confirmed in Buckinghamshire. All known sites have been subject to an extensive pheromone based trapping programme by the Forestry Commission.

This pest threatens between 29.9 and 51 percent of the population, which represents a potential loss of £22.7 - £39.4 million in replacement cost.

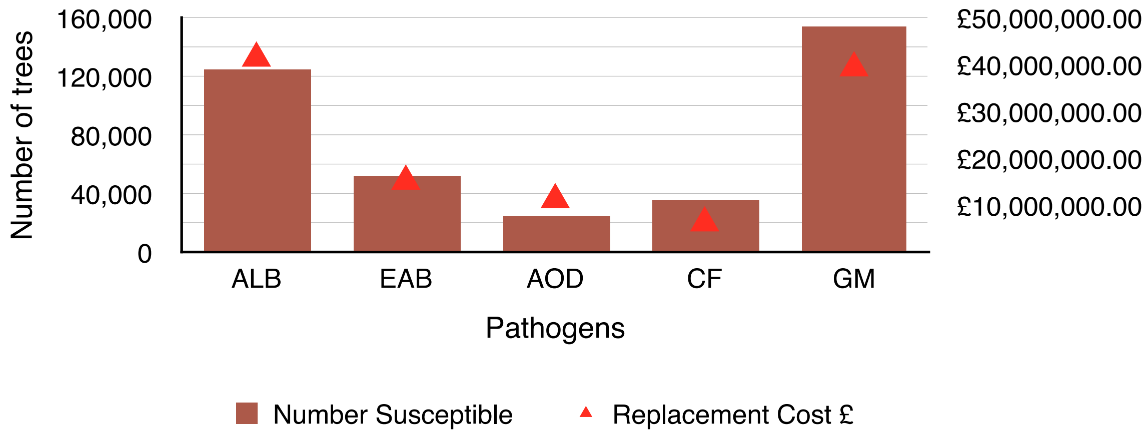


Figure 18: Potential number of trees affected by pathogens and the cost of replacement.

[25] http://silviculture.org.uk/ash-dieback-disease/

[26] USDA FS Potential effect of anoplophora glabripennis on urban trees in the United States. Nowak David J. Journal of Economic Entomology 9491): 116 – 122.

Healthy, well maintained trees (like the Lime above) that have adequate, un-compacted rooting space are better able to deal with pests and diseases.

Trees that are stressed are more susceptible to succumb and less likely to recover from these issues.

It is therefore important to ensure that trees are properly planted and maintained.

By far the most important factor when dealing with any potential pest or disease impact is to consider the health of the tree. Tree condition was measured as part of the survey and fig 19 below shows the overall health of the trees in Area 1.

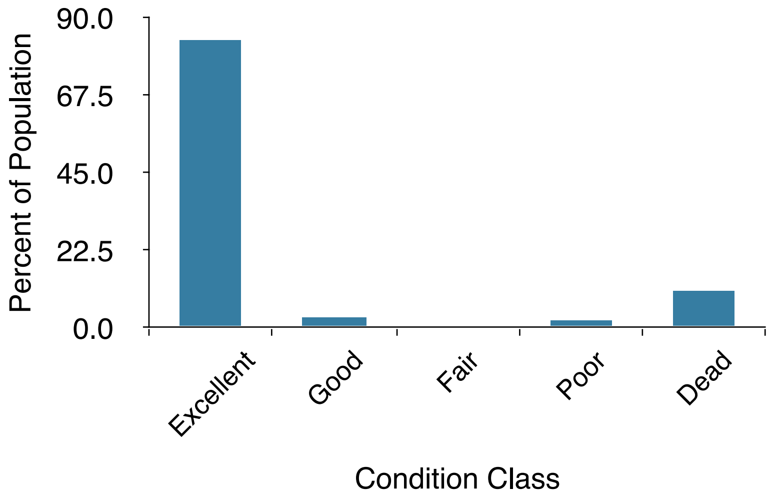


Fig: 19 Overall tree condition.

Over 86% of the trees in Area 1 are in either excellent or good condition (exhibiting less than 5% dieback). The small amount of dead trees (10%) is also acceptable as they are very important for biodiversity. Fig 20 shows the health of the 10 most common trees in Area 1. Although not a common tree, by far the least healthy of all trees encountered was the mountain ash (*Sorbus aucuparia*), of these over 40% were found to be in a 'poor' condition.

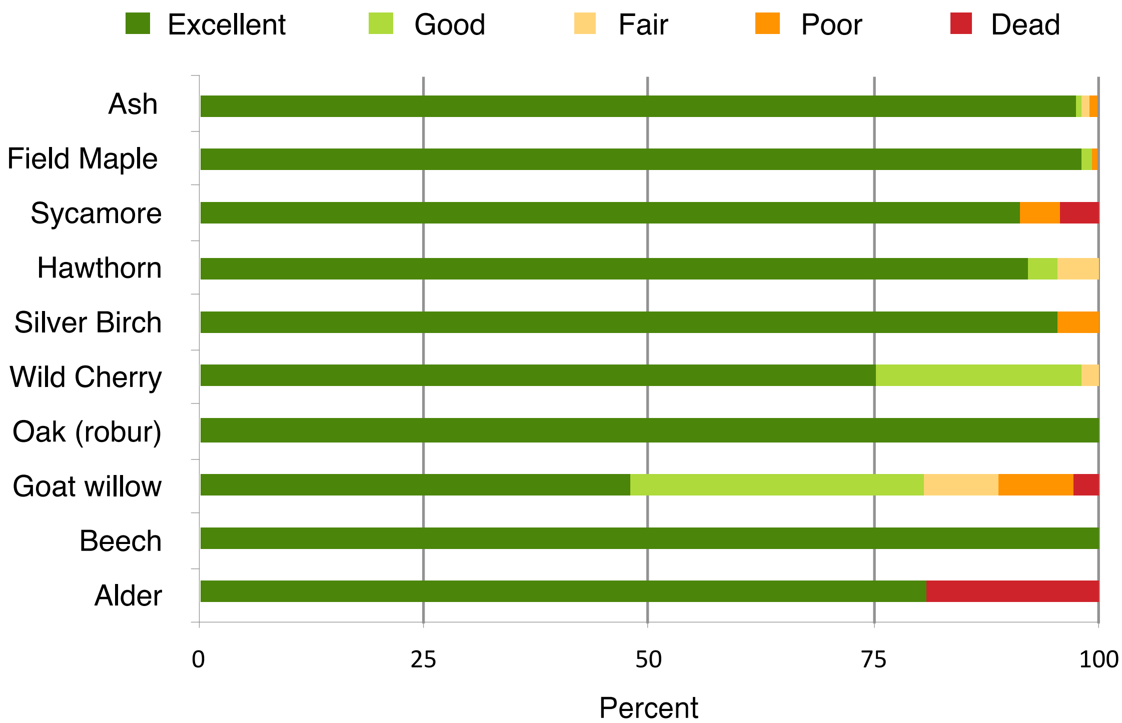


Fig 20: Condition of the 10 most common trees in Area 1.

Vegetation Maintenance & Management

Most of the trees and shrubs within the Area 1 HA network were planted, with the remainder being self seeded. As the network matures, the proportion of the latter increases. Generally however many trees will require maintenance for example to prevent them from encroaching on the carriageway, and management to encourage a healthy stable tree stock of appropriate species and structure given their location.

Table 11 (below) is the result of a simple financial comparison which indicates that the Area 1 soft estate generates benefits which outweigh the annual maintenance costs by some margin. Please note that the figures relating to benefits do not allow for topics such as biodiversity and are therefore underestimates.

Item	Description	Pence m^2 p.a.
1	Value of benefits provided by typical woodland compartment.	15
2	Value of benefits provided by trees when averaged across the entire soft estate.	8
3	Typical annual cost of maintaining the entire soft estate (i.e. inc grassland).	0.07

Table 11 – Comparison of typical annual costs and benefits within the Area 1 soft estate.

Notes:
Items 2 & 3 relate to the entire soft estate within Area 1 (including grassland) to enable a comparison over an identical area. Item 3 includes maintenance costs eg: swathe cuts and removing encroaching vegetation, but not management activities such as thinning.

If managed appropriately, as the tree population matures within the Area 1 network it will become increasingly self-sustaining over time requiring both less management and maintenance. This reduces, costs and minimises detrimental environmental impacts from herbicide use for example.

Screening

Within the Area 1 network and in accordance with the Highway Agency's 'Environmental Information System' (EnvIS), woody compartments are typically allocated one of three functions; integration, amenity or screening. A screening function will often be allocated where for example a compartment exists between adjacent residential properties and vehicles using the network.

Ascribing a financial value to the benefits of screening provided by vegetation is not straightforward due to the range and extent of variables involved. These include the width, composition and structure of the vegetation, plus seasonal variations. In addition, an individual's perception of the visual impact of the network varies, and may also be influenced by a range of factors. As an alternative to providing screening by the use of vegetation, screening may also be provided by a range of alternative structures such as larch lap or woven willow fences. Typically the latter will provide low level screening only, and have a typical life span of 8 - 12 years.

Within Area 1 there are approximately 237 ha of vegetation compartments that have been allocated with a screening function. These compartments run parallel to the carriageway for approximately 394 km. The latter figure seems high because the compartments are located adjacent to both sides of the trunk road, run parallel to junctions and side roads, and in some locations are also found within the central reservation. Using the figures already generated per m^2 for vegetation establishment, maintenance and management, this would suggest the cost of providing this screening over a 100 yr period as being approximately £64m. As this screening could have been at least partly provided by the use of fencing, it is of interest to briefly consider the relative costs between the two approaches.

Whilst the degree of screening achieved by the use of vegetation and fencing may vary, a simple comparison of costs incurred over a 100 year period would indicate that the typical cost of establishing, managing and maintaining trees and shrubs within a 12m wide and 100m long strip of planting is approximately half of the cost per linear metre of supplying, installing and maintaining for example a woven willow fence with a 10 year lifespan over the same length. The same calculation over a 50 year period indicates vegetation costs as being two thirds as the cost of fencing. It is not until the comparison period is reduced to less than 5 years that the costs of both approaches approximately equalise. These figures are again estimates based on recent Area 1 works prices see fig 21 (below).

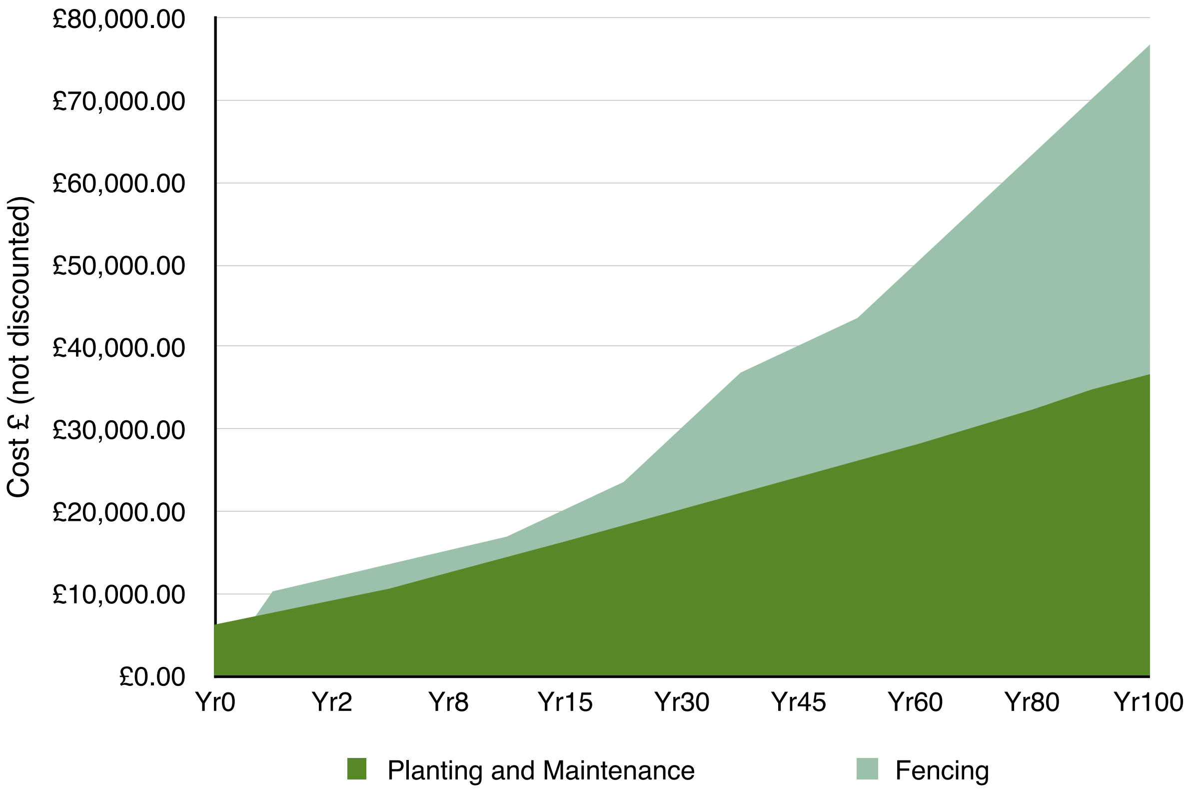


Figure 21: Costs of screening fencing compared to planting and maintenance (cumulative).

There are however situations where the installation of fencing and the increased associated costs may be appropriate. These may include for example, where the verge is narrow or where screening is required in the short term whilst vegetation becomes established.

Improved i-Tree Eco values with vegetation management

Following planting, woodland compartments within the Area 1 network should be managed in order to achieve the original functions as allocated according to EnvIS.

In relation to the benefits assessed by iTree, the trees that offer the greatest benefits are those that are larger and therefore have a greater canopy cover. This is because leaf area is the driving force of tree benefits, increasing their capacity to store carbon and filter pollution etc…

In order for this to be realised trees need to be able to achieve larger canopy. This can be achieved through appropriate thinning and management, species selection and planting location.

Additional to the quantifiable benefits, biodiversity value is also increased, maintenance costs are reduced, and the tree stock is of generally better quality, being less stressed. This in turn reduces the susceptibility of trees to pests and diseases. Woodland compartments that are not managed are much less likely to achieve these objectives.

Future projects developed from Area 1 i-Tree Eco findings

As a result of the data generated by this project, future projects within the Area 1 network can be both identified and prioritised accounting for localised benefits to nearby residents and passing motorists. Typical projects are likely to focus upon:

- Management of existing vegetation in or adjoining residential areas to guide the vegetation composition and structure in order to maximise benefits including increased oxygen production and associated pollution removal. The aim would be to create a healthy multi-layered vegetation structure, which is age and species diverse. Preferred species will vary from site to site but in general will be those that develop a large stature and high level of leaf area, and those which are long lived and of the most benefit for carbon storage. Due to the extent of nearby populations adjoining the network, locations for such an approach are likely to include Plymouth, Exeter, Liskeard and Okehampton. For the same reasons, such areas are also likely to be a focus for future planting projects where benefits can be maximised.

- In areas where storm water runoff levels are assessed as nearing existing drainage capacity, vegetation can be managed to provide increased buffering.

- Guide the design and implementation of mitigation works following construction activities within the Area 1 network.

- Guide the design and implementation of general tree stock management so that all compartments of adequate size develop to produce the maximum of benefits in conjunction with achieving the stated environmental function in accordance with EnvIS.

Recommendations

Pilot Study Recommendations

This project was a pilot study which focused on the natural capital (the trees, shrubs, grasses and soils) of the Area 1 soft estate. Having completed this pilot study it is appropriate to consider what changes would be suggested should a similar study be repeated elsewhere on a highways network.

- Not base survey field data around EnvIS 'function' due to limited use and relevance of subsequent data.

- Utilise and develop EnvIS vegetation 'type' data, to provide network level results and greater means to analyse and prioritise end results. Depending on quality of network data it may be necessary to 'ground truth network data' prior to survey commencing.

- Consider comparison of managed versus unmanaged vegetation compartments to demonstrate benefits of management activities.

- Establish links to network drainage data regarding, for example; existing capacity in grey infrastructure and where vegetation may be managed to provide additional stormwater attenuation to complement or reduce the need for grey infrastructure solutions.

- Use air pollution data to identify and assess potential opportunities to enhance the air pollution mitigation benefits of the HA soft estate.

- Allow plenty of time for data analysis, interpretation and review.

- Use data to influence network soft estate management when preparing strategies through to operational documents and to schedule the review of soft estate management documents together with the commissioning of future i-Tree Eco studies to ensure findings can rapidly be fed in to optimise operation.

- Look at links with other potential data sources, for example,

    Using Noise Important Area data to identify and assess potential opportunities to enhance the noise mitigation and screening benefits of the soft estate where there is adequate width of vegetation.

    Use vegetation-related complaints data for targeted analysis of local vegetation characteristics and associated benefits.

    Use data on localised flooding and drainage issues to identify and assess potential opportunities to enhance the water management benefits of the soft estate.

    Use Protected Landscape data (ie National Park, AONB boundaries, etc.) to to help prioritise potential opportunities to enhance the biodiversity benefits of the soft estate."

Recommendations for using this study

The results and data from previous i-Tree studies have been used in a variety of ways to better manage trees and inform decision making. With better information we can make better decisions and this is one of the biggest benefits from undertaking a project such as this.

- Data can be used to inform species selection for increased tree diversity thereby lessening the impacts from potential threats like emerald ash borer.
- Use the report and data to produce educational and public information around Area 1’s trees.
- Use the data for cost benefit analysis to inform decision making.
- Use the findings and method demonstrated in this study to inform the performance framework under development to monitor the impact of the soft estate on Biodiversity.
- Use the approach and findings presented in this report to inform the development of Highways England’s Environment Strategy due to be published in 2016.
- Encourage Highways England's future Design Review panel to use the benefit evaluation framework exemplified in this report to assess project proposal (upcoming development of i-Tree Eco in the UK -from May 2015- will allow to forecast benefits on the basis of a proposed designed). This could enable the panel to assess the merit of the proposed landscaping based on both aesthetics and anticipated performance in respect to local or network-wide priorities.
- Use the findings from this report to put together a business case for drawing from Highways England £75 Million Air Quality Fund to fund some targeted enhancements to the Area 1 soft estate where air pollution issues are most acute.

“We need a diversity of trees, not only to guard against disasters like Dutch elm disease, but also to ‘put the right tree in the right place“

Frank Santamour

Conclusions

The tree canopy cover in Area 1 is above the UK average (based on both rural and urban estimates). In addition, Area 1 has a fair diversity of tree species which will provide some resilience from possible future influences such as pests and diseases.

The range of benefits from trees within Area 1 are diverse, and when valued in financial terms significantly outweigh the annual cost of maintenance.

The concept of trees as part of our public health infrastructure is a reality.
Area 1’s trees provide a valuable public benefit - at least £ 794,000 in environmental services each year.

Furthermore, the values presented in this study represent only a portion of the total value of the soft estate of Area 1 because only a proportion of the total benefits have been evaluated. Trees confer many other benefits, such as journey quality and habitat that cannot yet be factored in. Therefore, the values presented in this report should be seen as conservative estimates.

The extent of these benefit needs to be recognised, and strategies and policies that will serve to conserve this important resource (through stakeholder education for example) would be one way to address this.

There is potential for the tree stock to develop in the future, and provide greater benefits. As the amount of healthy leaf area equates directly to the provision of benefits, future management of the tree stock is important to ensure canopy cover levels continue to increase.

This may be achieved via new planting, but the most effective strategy for increasing average tree size and the extent of tree canopy is to preserve and adopt a management approach that enables the existing trees to develop a stable, healthy, age and species diverse, multi-layered population.

Climate change could affect the tree stock in Area 1 in a variety of ways and there are great uncertainties about how this may manifest., Further research into this area would be useful in informing any long term tree and woodland strategies such as species choice for example.

The challenge now is to ensure that policy makers and practitioners take full account of trees and woodlands in decision making. Not only are trees a valuable functional component of our landscape they also make a significant contribution to peoples quality of life.

Afterword

Highways England (HE) – a government-owned Company - will be replacing the Highways Agency from April 1st.

This follows the development of a Road Investment Strategy by Government that will be delivered through HE.

HE's response to the Road Investment Strategy is a delivery plan for the first 5 years of the reporting period (ie Reporting Period 1 – RP1): Highways England Delivery Plan 2015-2020.

This delivery plan is structured around the following 5 strategic outcomes

(1) supporting economic growth,
(2) a safe and serviceable network,
(3) a more free-flowing network,
(4) an improved environment
(5) a more accessible and integrated network

Trees and landscaping can contribute to the delivery of 4 out of 5 of these objectives - and can have a direct impact on at least 2 Key Performance Indicators (KPIs), as well as a number of Performance Indicators (PIs) and Requirements that HE is expected to report to Government on.

For example in (1) Supporting economic growth throughout the country, trees affect the perception of drivers/users of roadside communities.

Trees also assist with perception/anticipation of road geometry; tree provide an effective windshield; trees create an 'appeasing roadside' helping to reduce stress and associated potential impacts on driver behaviour. Trees also contribute to stormwater management and flood prevention, and ensure embankment stabilisation thereby enhancing safety and serviceability (2).

With regard to enhancing the environment (4), trees provide effective visual screening and may also contribute moderate noise attenuation (where there is sufficient depth of vegetation), but they also reduce airborne pollutants and support biodiversity.

Trees and landscaping can enhance the 'usability' of network crossings and other routes provided along the network for vulnerable users thereby enhancing integration and accessibility (5). Trees also enhance the visual integration of the trunk road network within the wider landscape.

This i-Tree report articulates the potential for trees and natural capital on the Area 1 soft estate, and recommends for roadside vegetation to be managed as a functional asset, making a positive contribution to the delivery of the 4 objectives HE is committed to.

Vegetation isn't just synonymous with 'aesthetics' or 'biodiversity', but is also understood as having 'functional attributes' that can be optimised in light of both maintenance requirement (safety, costs) and HE key priority outcomes.

Appendix I. Comparison of Urban Forests

How does this Area 1 compare to other areas? A true comparison cannot be made until there are further studies carried out on similar 'Highways Areas'. Comparison with cities at the global scale is interesting but should be made with caution as there are many attributes of a city which will effect urban forest structure and function. Summary data are provided here from other cities analysed using the UFORE i-Tree Eco model.

City totals, trees only

City	% Tree cover	Number of trees	Carbon storage (tons)	Carbon sequestration (tons/yr)	Pollution removal (tons/yr)	Pollution value U.S. $ and £
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663	12,213,000
Area 1	**34.9**	**303,000**	**22,200**	**1,980**	**29**	**£611,000**
Toronto, Canada	20.5	7,542,000	992,000	40,300	1,212	8,952,000
New York, NY	20.9	5,212,000	1,350,000	42,300	1,677	11,834,000
Chicago, IL	17.2	3,585,000	716,000	25,200	888	6,398,000
Baltimore, MD	21.0	2,627,000	597,000	16,200	430	3,123,000
Glasgow, UK	15.0	2,000,000	183,000	9,000	283	£4,825,888
Washington, DC	28.6	1,928,000	526,000	16,200	418	2,858,000
Barcelona, Spain	25.2	1,419,823	113,437	6,187	305	1,579,873
Boston, AM	22.3	1,183,000	319,000	10,500	284	2,092,000
Woodbridge, NJ	29.5	986,000	160,000	5,560	210	1,525,000
Minneapolis, MN	26.4	979,000	250,000	8,900	306	2,242,000
Syracuse, NY	23.1	876,000	173,000	5,420	109	836,000
Edinburgh, UK	17.0	600,000	145,611	4,721	100	£2,300,000
Wrexham, UK	17.0	364,000	66,000	1,300	60	£800,000
Torbay, UK	11.2	818,000	98,100	4,279	50	£1,400,000
Udine, Italy	10	162,000	19,100	888	80	463,000
Freehold, NJ	34.4	48,000	20,000	545	22	162,000

Source: USDA Forest Service and Treeconomics

Appendix II. Relative Tree Effects

The soft estate in Area 1 provides benefits that include carbon storage and sequestration and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average carbon emissions and average passenger automobile emissions. These figures should be treated as a guideline only as they are largely based on US values (see footnotes).

Carbon storage is equivalent to:

- Annual carbon (C) emissions from 14,700 family cars
- Annual C emissions from 7,360 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 231 family cars
- Annual nitrogen dioxide emissions from 154 single-family houses

Particulate matter less than 10 microns (PM10) removal is equivalent to:

- Annual PM10 emissions from 31,100 family cars
- Annual PM10 emissions from 3,000 single-family houses

Annual carbon sequestration is equivalent to:

- Annual C emissions from 1,300 family cars
- Annual C emissions from 700 single-family houses

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

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

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO_2 Emissions. Climatic Change 22:223-238).

Appendix III. Species Importance Ranking List

Rank	Genus	Species	Common Name	% Population	% Leaf Area	IV [a]
1	*Fraxinus*	*excelsior*	Ash	17.1788	20.7136	37.8924
2	*Acer*	*campestre*	Field maple	13.1552	15.265	28.4202
3	*Acer*	*pseudoplatanus*	Sycamore	9.5843	14.9562	24.5405
4	*Crateagus*	*monogyna*	Hawthorn	9.7289	4.4008	13.7055
5	*Fagus*	*sylvatica*	Beech	4.7059	7.1472	11.8531
6	*Prunus*	*avium*	Wild Cherry	6.154	5.5203	11.6743
7	*Salix*	*caprea*	Goat willow	5.1755	5.8678	11.0433
8	*Betula*	*pendula*	Birch	6.6925	4.1416	10.8341
9	*Quercus*	*robur*	Pendunculate oak	5.8879	4.2574	10.1453
10	*Salix*	*cinerea*	Grey willow	4.2749	3.0111	7.286
11	*Alnus*	*glutinosa*	Alder	4.4355	2.5313	6.9668
12	*Pinus*	*sylvestris*	Scots Pine	2.1633	3.1379	5.3013
13	*Quercus*	*petrea*	Sessile oak	1.852	1.8861	3.7381
14	*Corylus*	*avelana*	Hazel	2.4041	1.1636	3.5677
15	*Populus*	*spp*	Poplar	1.269	1.0313	2.3003
16	*Quercus*	*x hispanica*	Lucombe oak	0.157	1.4118	1.5688
17	*Sorbus*	*aucuparia*	Mountain ash	1.0032	0.3199	1.323
18	*Quercus*	*cerris*	Turkey oak	0.5801	0.4522	1.0323
19	*Fraxinus*	*augustifolia*	Narrow-leafed ash	0.126	0.7666	0.8925
20	*Ulmus*	*glabrs*	Wych elm	0.3779	0.4522	0.8301
21	*Taxus*	*baccata*	English yew	0.6282	0.1875	0.8157
22	*Sambucus*	*nigra*	Elder	0.801	0	0.801
23	*Pinus*	*nigra*	Austrian pine	0.3139	0.3585	0.6724
24	*Carpinus*	*betulus*	Hornbeam	0.3139	0.1489	0.4628
25	*Sorbus*	*torminalis*	Wild service tree	0.157	0.2482	0.4051
26	*Acer*	*platanoides*	Norway maple	0.126	0.2482	0.3741
27	*Sasanqua*	*camellia*	Eastern camellia	0.126	0.182	0.308
28	*Ilex*	*aquifolium*	Holly	0.157	0.1048	0.2618
29	*Salix*	*alba*	White willow	0.157	0.0551	0.2121
30	*Populus*	*alba*	White poplar	0.157	0.0331	0.1901
31	*Rhododendron*	*spp*	Rhododendron spp	0.157	0	0.157

IV [a] = importance value (% population + % leaf area)

Appendix IV. Tree values by species

Species	Number of trees	Carbon stored (mt)	Gross Seq (mt/yr)	Net Seq (mt/yr)	Leaf Area (km2)	Leaf Biomass (mt)	Replacement Cost (£)
Ash	52092	3,199.23	291.02	288.6	3.756	399.55	14874122
Field maple	39891	3,951.06	327.99	325.03	2.768	155.79	16476466
Sycamore	29063	3,361.12	240.79	233.41	2.712	189.62	12857842
Hawthorn	28215	853.66	125.92	125.22	0.798	100.42	3880383
Silver birch	20294	999.43	128.04	127.18	0.751	44.62	4037373
Wild cherry	18661	1,707.73	147.71	146.44	1.001	77.43	6282165
English oak	17854	1,119.44	114.69	113.85	0.772	51.39	4724437
Goat willow	15694	881.45	91.38	89.67	1.064	67.42	3763116
Beech	14270	1,284.06	133.62	132.66	1.296	64.83	4445156
Alder	13450	725.96	75.13	71.61	0.459	33.46	2979469
Grey willow	12963	701.47	81.35	80.8	0.546	34.59	3321212
Hazel	7290	176.8	30.56	30.41	0.211	14.66	913896
Scots pine	6560	478.74	28.94	27.63	0.569	54.85	3343146
Sessile oak	5616	1,376.77	73.75	72.76	0.342	33.78	4491335
Balsam poplar	3848	104.27	15.5	15.42	0.187	13.46	703081
Mountain ash	3042	31.63	7.98	7.91	0.058	4.58	181633
Elder	2429	139.53		-6.98			
Yew	1905	11.65	2.73	2.72	0.034	5.35	119057
Turkey oak	1759	99.19	12.93	12.85	0.082	8.12	445614
Hawthorn spp	1283	6.91		-0.35			
Wych elm	1146	82.51	7.97	7.91	0.082	5.62	271697
Hornbeam	952	13.91	3.34	3.33	0.027	1.64	77276
Austrian pine	952	56.14	4.37	4.33	0.065	6.26	469348
Holly	476	8.83	1.83	1.82	0.019	2.47	39923
White poplar	476	1.9	0.61	0.61	0.006	0.54	29764
Lucombe oak	476	578.5	18.91	18.5	0.256	25.22	1678605
Rhododendron spp	476	4.57		-0.23			
White willow	476	11.78	2.31	2.3	0.01	0.65	55761
Wild service tree	476	62.5	5.27	5.22	0.045	3.56	279150
Norway maple	382	6.68	1.55	1.54	0.045	2.43	26466
Sasanqua camellia	382	52.11	4.27	4.23	0.033	2.45	210811
Narrow-leafed ash	382	79.9	4.23	4.17	0.139	9.89	413935

Appendix V. Notes on Methodology

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

- Forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by trees, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns and <10 microns).
- Total carbon stored and net carbon annually sequestered by trees.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

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

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations[27]. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

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

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of trees account for decomposition[28].
Recent updates (2011) to air quality modelling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values [52, 53, and 54].

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27 Nowak 1994

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

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models[29]. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature[30] [31] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[32].

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

Replacement Costs were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition and location information[33] [34].

For a full review of the model see UFORE (2010) and Nowak and Crane (2000).
For UK implementation see Rogers et al (2014).
Full citation details are located in the bibliography section.

29 Baldocchi 1987, 1988

30 Bidwell and Fraser 1972

31 Lovett 1994

32 Zinke 1967

33 Hollis (2007)

34 Rogers et al (2012)

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