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Research Project

Sharing the best in Gardening

Street Trees in the UK's Towns and Cities:

A review of concepts, policies and practices, concerning their effects on the twenty-first century urban forest.

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Abstract

It has been known for some time that urban greenspace and trees in particular can help mitigate the effects of climate change and improve the lives of inhabitants.
In the UK this concept has accrued value over the last two decades, but it is still unclear whether policy is enabling positive change, keeping pace with research, or implementing best practice.

Presenting a review of the current state of the urban realm, its development and management, and highlighting the role of street trees as an important component of urban green infrastructure, this research paper recommends an improved planning framework to ensure the long-term resilience of the UK's urban forest.

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Introduction

Approximately 75 percent of the population of the European Union (EU) are currently living in urban and peri-urban areas, which has increased from 70 percent in 2013 and is continuing to rise (EU, 2013). In the United Kingdom (UK), approximately 90 percent of the population live in urban areas (Goodwin, 2017). This growth aligns with the global trend, which has risen from 16.4 percent at the turn of the twentieth century to 55.7 percent in 2019 and is forecast to reach 85 percent by 2100 (European Commission, 2018; Ritchie & Roser, 2019; Central Intelligence Agency, 2019) (table 1).

Table 1: Urbanisation growth and projection 1900-2100.

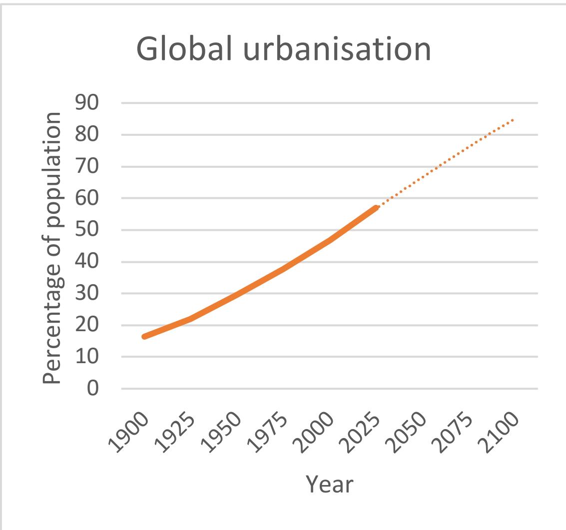
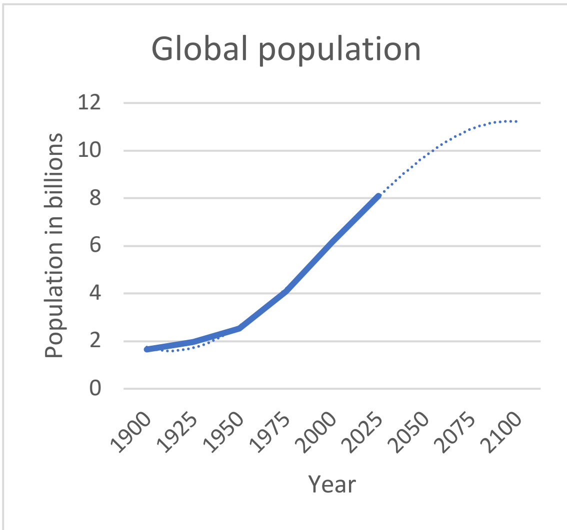


Table 2: Population growth and projection 1900-2100.



Combined with population growth, which the United Nations (UN) predicts will continue ascending until stabilising around 11.2 billion by 2100 (Roser, 2019) (table 2), this represents a situation where greenspace is under greater pressure than ever before. Land is at a premium and such spaces "are often the first casualties as cities build, bulldoze and expand to accommodate their burgeoning populations" (Lopez, *et al.*, 2018).

Given the intensification of this challenge in the light of the climate crisis, this research paper seeks to understand how current street tree planting concepts, policies and practices are shaping the UK's urban forest. It aims to evaluate how effectively the UK is currently managing street tree planting in order to promote sustainable development and create multifunctional towns and cities. In order to achieve this, terms and concepts within the literature are defined; historical perspective is given to the integration of trees in planning policy; services and disservices are scrutinized; and the evolution of practices is examined with reference to recent planting projects and asset management tools.

Literature review and research

Definition of urban

Towns and cities are characterised by their “high density of people, buildings and constructed infrastructure” (Auch, *et al*., 2016, p. 247). In the UK, the Office for National Statistics (ONS) defines built-up areas with populations of 10,000 or more people as urban (ONS, 2015).

Sustainable urbanisation

While urban growth offers opportunities to improve the standard of living, it requires careful management of the increase in demand for resources to avoid social, economic and environmental degradation (UN, 2018). This concept was formulated in a report by the UN, giving rise to the term *sustainable development*, meaning, “[meeting] the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). Its influence endures in contemporary policy, for example chapter 2 of the National Planning Policy Framework (NPPF), ‘Achieving sustainable development’ (Ministry of Housing, Communities and Local Government, 2019).

Numerous organisations have published a wealth of research which demonstrates the multiple benefits derived from nature in the built environment, particularly its potential for improving habitability in support of sustainable development (Trees and Design Action Group (TDAG), 2012, 2014; Urban Forestry and Woodlands Advisory Committee Network (UFWACN), 2018). In a setting where space is increasingly limited, however, the challenge for innovative urban planning is plain, as, “the city must become greener whilst it also becomes denser and more compact” (London Urban Forest Partnership (LUFP), 2020, p. 16).

The fundamental role of green infrastructure

The literature of urban trees frequently refers to the terms, *urban green infrastructure* (urban-GI) and the *urban forest* (Roloff, 2016). The former, used interchangeably in the literature with terms such as *greenways* (Searns, 1995), *urban green* and *greenspace* (Doick, *et al*., 2016a), is the urban application of a concept given expression in the United States (USA), in a report recommending enhanced integration of nature in Florida's built environment (Firehook, 2015, cited in Goodwin, 2017). The term *green infrastructure* (GI) was coined to demonstrate that natural systems require planning, funding, protecting and managing in much the same way as constructed infrastructure. The concept has evolved to encapsulate a strategically organised "network of multi-functional green space" (Ministry of Housing, Communities and Local Government, 2019, p. 67), including parks, gardens, woodlands, cemeteries, sports fields, and all public and private natural assets in both urban and rural environments. Swanwick, *et al*., (2003) developed a typology of urban-GI in order to depict the breadth of resources, their catchment areas and the types of amenity provided (table 3). This could be a useful starting point for Local Authorities (LAs) to inventory their GI and identify areas for growth.

The allusion to multifunctionality relates to the multiple, measurable and well-documented ecosystem services provision of GI (Cameron, 2016a), and to the understanding that environmental, social and economic systems are connected (UK Stakeholders for Sustainable Development , 2017). This has helped validate its role in political policies at local, national and international levels (UFWACN, 2016; European Environment Agency, 2017).

Table 3: Typology of urban green infrastructure (Swanwick, *et al*., 2003).

MAIN TYPES OF GREENSPACE			
ALL URBAN GREEN SPACE	Amenity Green Space	Recreation Green Space	Parks and gardens
			Informal recreation areas
			Outdoor sports areas
			Play areas
		Incidental Green Space	Housing green space
			Other incidental Space
		Private Green Space	Domestic gardens
	Functional Green Space	Productive Green Space	Remnant farmland
			City farms
			Allotments
		Burial Grounds	Cemeteries
			Churchyards
		Institutional Grounds	School grounds (including school farms and growing areas)
			Other institutional grounds
	Semi-natural habitats	Wetland	Open/running water
			Marsh, fen
		Woodland	Deciduous woodland
			Coniferous woodland
			Mixed woodland
		Other Habitats	Moor/heath
			Grassland
			Disturbed ground
	Linear Green Space		River and canal banks Transport corridors (road, rail, cycleways and walking routes)
			Other linear features (e.g. cliffs)

Climate crisis

GI planning has gained political momentum in recent years, owed largely to worldwide climate agreements (UN, 2015), becoming central to a range of planning and environmental policies and strategies in the UK (as in, NPPF, 2019). The UK Government has highlighted the role of GI in urban areas as “essential to both [their] environmental sustainability and long-term social and economic success” (Town and Country Planning Association (TCPA), 2008). The timing of this statement in the Government-supported publication, *The Essential Role of Green Infrastructure*

(TCPA, 2008), coincided with legislation to reduce the impacts of climate change (Climate Change Act 2008), in response to European policy urging countries to adopt climate change mitigation and adaptation strategies (European Commission, 2007).

However, degeneration of urban greenspace had been officially recognised many years earlier, for example in *People, Parks & Cities* (Greenhalgh & Worpole, 1996) and *Town and Country Parks* (Environment, Transport and Regional Affairs Committee, 1999), securing government commitment to ensure improvements, resulting in the formation of the Urban Green Spaces Taskforce (UGST) (Committee of Public Accounts, 2006). Reflecting on the years passed since the final report by the UGST (2002), *Trees in Towns II* (Britt & Johnston, 2008) noted “a halt in the decline of the quality of green spaces in many neighbourhoods” (p. 7) but stagnant funding and threats of litigation inhibited LAs from protecting and enhancing the urban tree resource. An important factor facilitating the halt in decline was legislation replacing Compulsory Competitive Tendering policy with Best Value policy, shifting the emphasis from low-cost (inputs) to high returns (outcomes) for users, mandating LAs to explore best practice (Local Government Act 1999, cited in Gordon & Shirley, 2002).

Notwithstanding the support for urban greening, new legislation that is progressing through parliament at the time of writing (Environment Bill 2020), admits that, “despite recent positive action, we have not been able to reverse [the] long-term decline in nature” (Department for Environment, Food and Rural Affairs, 2020). In a more urgent tone, marked by a transition from referring to *climate change* to the *climate crisis*, it reinforces the value of green spaces and sets a new “requirement for biodiversity net gain in the planning system” (ibid). This is concurrent with intensifying society-wide awareness and mobilisation in the UK, from the 454 local councils who have declared a climate emergency (International Climate Emergency Forum, 2020), to the 62 percent of surveyed UK adults who believe government is doing too little to tackle the crisis (YouGov & ClientEarth, 2018).

Component of green infrastructure: the urban forest

Urban forestry is a term that was created in 1965 at the University of Toronto as a means to distinguish the study of municipal tree populations apart from one of its components, arboriculture, which relates to the study and management of single trees (Jorgensen, 1986; Food and Agriculture Organization of the United Nations (FAO), 1993). In the UK the agency responsible for providing expert advice to the Government, Forest Research, defines the urban forest (UF) as a critical element within GI, concerned only with the trees in and around urban areas (Doick, *et al*., 2016b). Conversely, in the study by the RE:LEAF partnership, *Valuing London's Urban Forest* (Rogers, *et al*., 2015), of which the Forestry Commission was a partner, the UF is defined as "the ecosystem containing all of the trees, plants and associated animals in the urban environment" (p. 3) and "the millions of trees and shrubs in [and around London]" (p. 9). Despite this ambiguity, the purpose of this type of forestry is "to improve the quality of human life in the city" (Da and Song, 2008, cited in Auch, *et al*., 2016).

Recognising the case for investment

Valuing the UF has evolved from appreciation of its recreational and aesthetic properties, following Searns (1995) description of an emerging interdisciplinary form of urban development that traversed the fields of,

> "…civil engineering, landscape architecture and wetland ecology to address… such areas as habitat needs of wildlife, promoting urban flood damage reduction, enhancing water quality, providing a resource for outdoor education, and other urban infrastructure objectives."

Searns' research coincided with a period in UK history of, "low investment, low resources and low priority" (Gordon & Shirley, 2002) in relation to urban greenspace. This was observed in a series of key reports in the mid-1990s, notably *Park Life* (Greenhalgh & Worpole, 1995) and *Parks, People and Cities* (Greenhalgh & Worpole, 1996) for their effect in highlighting the extent of decline, championing the benefits of greenspace, and provoking the political will to act (Swanwick, *et al*., 2003).

It has been established in the intervening decades that the UF makes a "valuable contribution across the spectrum of social, environmental and economic benefits" (ibid., p. 103). Its management and strategic expansion can address many of the environmental challenges faced globally, including urban heat islands, air and water quality, extreme weather events, biodiversity loss and energy management (Costanza, *et al*., 1997; Town and Country Planning Association, 2008; Cameron & Blanuša, 2016; TDAG, 2019a).

Political support has been facilitated by supplementing the qualitative evidence-base with economically quantifiable data by means of increasingly sophisticated data capture and modelling technology, for example i-Tree Eco projects in the UK, including London (Rogers, *et al*., 2015). It is thus the term *ecosystem services* can be defined as, "the benefits provided to society by the natural environment that can be priced into economic calculations" (Forest Research, 2018, p. 10). Resulting from such studies, investment in urban-GI has been recognised as "more cost effective, more resilient and more capable of meeting social, environmental and economic objectives than 'grey' infrastructure" (UN, 2017) and capable of bringing "higher returns than constructed or manufactured alternatives, with lower up-front costs" (European Commission, 2011a).

The output of trees is the focus of much research, establishing them as the most important component of urban-GI (Forestry Commission, 2010; Hand & Doick, 2019; Ministry of Housing, Communities and Local Government, 2019). Their immense potential has prompted some to reason that trees should be acknowledged a form of "critical infrastructure, similar to utilities or transportations" (FAO, 2018). In April 2020, when the conference *Trees, People and the Built Environment* was planned to take place, UK and international experts were due to showcase their work around the theme, 'Trees as Infrastructure' (Institute of Chartered Foresters, 2020).

Professor of Urban Forestry, Alan Simson (2019, pers. comm.), who co-organised the 1st World Forum on Urban Forests (FAO, 2018), explained, "the big change in the last few years is that trees are no longer just seen as cosmetic, but as a metaphysical first principle; that is, they are so fundamental that you cannot deliver any of green, blue or grey infrastructure if you don't get the trees right." The forum's

Call to Arms manifesto is now promoted as a tool for delivering the UN's 2030 Agenda for Sustainable Development (2015), notably Goal 11, to make "cities and human settlements inclusive, safe, resilient and sustainable" (International Institute for Sustainable Development, 2016).

Component of the urban forest: street trees

Tree planting sites within the UF are highly variable, from inner city roadsides to public parks and woodlands, so there is a danger when conceptualising the UF that the term "obscures the broad range of different soil and microclimatic conditions that result from the history of building and settlement structure" (Gillner, *et al*., 2016, p. 196). In Gillner's criteria for urban tree species selection the types of location were categorised in terms of density of the surrounding built environment. The street trees considered in planting project examples in this research can be found in Gillner's two highest-density locations, "road traffic areas" and "densely built up areas" (ibid, p.202). These consist of residential and non-residential streets, verges, strips between lanes, intersections, parking spaces and pedestrianised areas; situations generally hostile to growth (figure 1).

It is in the urban centres, where the predicted effects of the climate crisis will be most keenly felt. Here a dichotomy exists where trees are expected to achieve a range of social and environmental objectives, mitigating the present and unavoidable future effects of climate change, while their effectiveness becomes increasingly hindered by climate extremes. These are expected to include higher air temperatures, unseasonal frosts, extended periods of drought, reduced dormancy periods and the arrival of exotic pests and diseases (Forest Research, 2018). These are potential sources of stress to urban street trees, "with consequences of reduced vitality [and] increased susceptibility to diseases and shortened lifespan" (Krabel, 2016, p. 211). This suggests two things: design and species selection must take into account anticipated future climate scenarios, and trees are required both to protect inhabitants and equally to protect other trees.

Figure 1: Plane trees (*Platanus* sp.) contribute significantly to the character of many London streets, including Smith Square, where they compete with ever-encroaching development. The Victorians secured the trees' long-term performance with extensive below-ground preparation works including supporting pavements on girders to reduce soil compaction (Johnston, 2017). Nearby, new plantings struggle to establish and suffer physical damage.

Multifunctional, simultaneous benefits

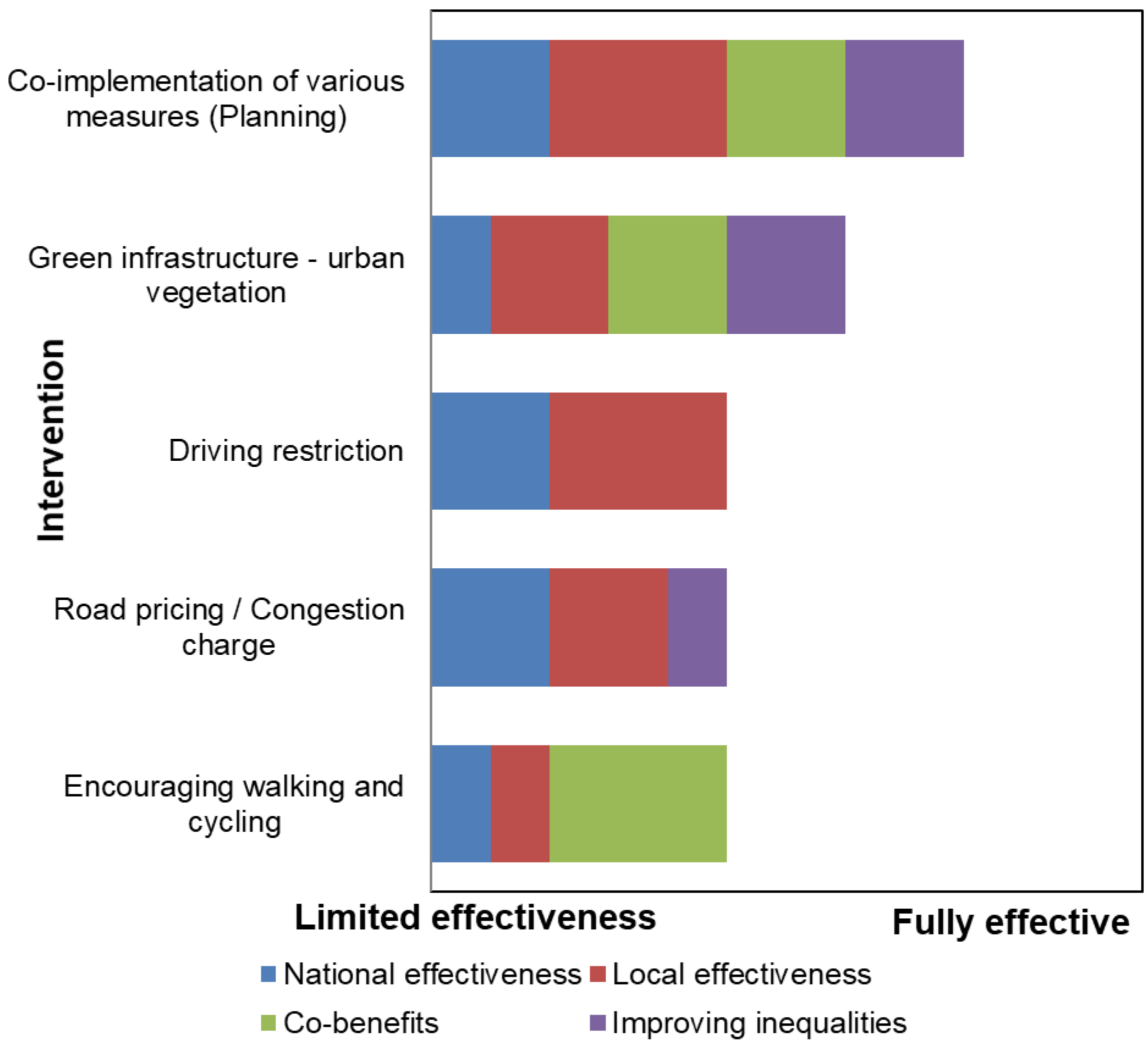
Since the 1940s temperatures in cities around the world have been increasing at a faster rate than their surrounding areas (Akbari, 2005). This phenomenon, termed the *urban heat island* effect, was first detected between 1806-1830 in London (Howard, 1833). It primarily stems from the replacement of vegetation with hard surfaces, such as pavements, roads and buildings, which reflect, absorb and re-radiate heat (Gill, *et al*., 2007). The mean temperature uplift in cities above surrounding rural areas is 4^{o}C, but variations in time of day and location produce a range between 2-11^{o}C, with city centres typically recording the highest (Cameron, 2016a; Goodwin, 2017). This places greater demand on energy for cooling systems, which account for 20 percent of global electricity consumption in buildings (International Energy Agency, 2018). This creates a feedback loop where operating vast numbers of power-hungry air conditioning units contributes to warmer temperatures, resembling, “in miniature, the problem we face in tackling the climate crisis” (Buranyi, 2019).

The associated financial and ecological costs of urban heat islands stem from higher energy use and the human health damage of exposure to excessive heat and urban particulates (Akbari, 2005; Goodwin, 2017). In another cyclical relationship, higher temperatures stimulate increased formation of air pollution, which subsequently generates warmth by absorbing and trapping longwave radiation in the atmosphere (Leibowicz, 2017).

In the UK, poor air quality is recognised as the most significant environmental risk to public health, causing between 28,000-36,000 deaths annually (Public Health England (PHE), 2020). The latest strategy to combat air pollution (ibid) cites green infrastructure as a key intervention, building on ONS (2018) evidence that found the pollution removed by vegetation in 2015 saved the economy an estimated £1 billion and prevented 1,900 premature deaths; it identifies trees, particularly in urban centres, as accounting for absorbing most of the volume of pollutants. PHE recommend their use as the part of a package of solutions, including lowering emissions and encouraging active transport (table 4).

A study of London’s 700,000 street trees (Tallis, *et al.*, 2011, cited in Goodwin, 2017; LUFP, 2020), found the reduction in pollution caused by existing trees to be between 0.7-1.4 percent (2241 tonnes of pollution), but increasing canopy cover by 50 percent by 2050 would raise this figure to the region of 1.1-2.6 percent. Greater London’s canopy cover is approximately 21 percent (Greater London Authority (GLA) & Curio Canopy, 2018a) and the target set by the London Environment Strategy for 2050 is 23 percent (GLA, 2018b), which represents only a 10 percent increase. This signifies that only a modest gain can be expected when viewing the pollution-reducing properties of trees in insolation, so investment must be spread across the full range of interventions. Advising a multifaceted approach long before the PHE publication, Whitlow, *et al.*, (2014, cited in Goodwin 2017, p. 13) cautioned the limitations of trees to remedy the situation, "the system has been pushed far beyond its biological capacity to compensate for human disturbances like air pollution." However, this single function of London's trees is still valued at over £126 million each year (Rogers, *et al*., 2015).

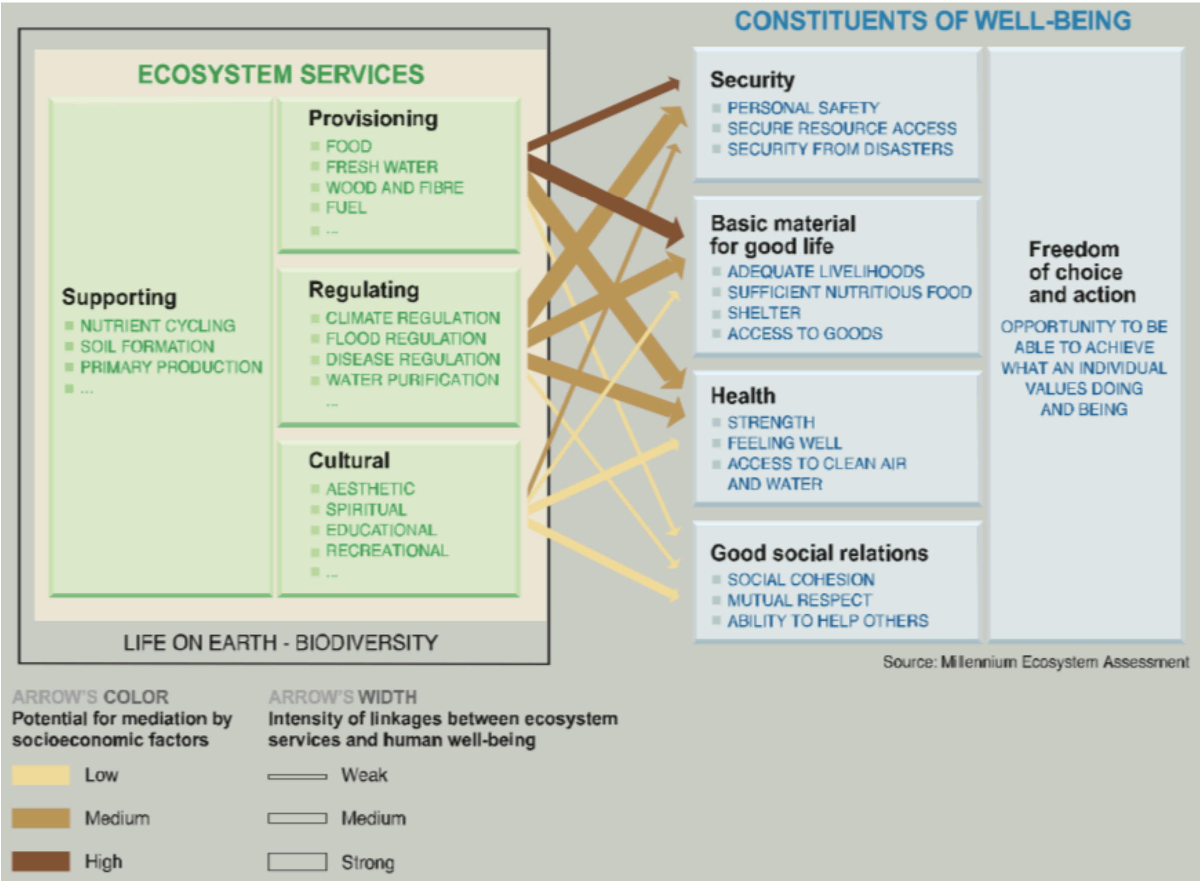
Table 4: Public health impacts of individual and combined planning interventions to improve air quality in urban areas (assets.publishing.service.gov.uk, 2020).



Other benefits

The ecosystem services of street trees fall into the 'regulating' and 'cultural' categories first outlined by the Millennium Ecosystem Assessment Board (MEAB). These include services that regulate aspects of the environment, for example climate, and perform aesthetic and socio-cultural functions in people's lives. The report identified these services as contributing to society's security, providing basic materials for life, improving health and social cohesion; collectively the "constituents of well-being" (ibid, p. 15), from which human potential can be achieved (table 5).

Table 5: Categories of ecosystem services and how they affect human well-being (Millennium Ecosystem Assessment Board, 2005).



Additional primary outputs include:

- **Cooling**: Through evapotranspiration, shading and reflection, urban trees have been shown to cool their urban surroundings by an average of 2°C to distances from 20 metres up to 2 kilometres, depending on their size, proximity with other trees and factors such as windspeed (Doick, *et al*., 2016a). A study of *Tilia cordata*, the second most common tree in Inner London (6.2% of the population), found 1-1.5°C cooler air temperature under the canopy compared to surrounding temperatures (Rahman, *et al*., 2018). Rogers, *et al*., (2015) calculated the reduction in heating costs resulting from trees insulating buildings against increased heating costs incurred by excessive shading, finding a net annual saving to London of £315,477 plus 882 tonnes of carbon, worth a further £55,000.

- **Stormwater**: Urban centres abound with impermeable surfaces, up to 40 percent in London (GLA, 2018b). Drainage systems are frequently tested to capacity from rainfall runoff, increasing flood risk and degrading waterbodies with polluted washoff (Environment Agency, 2013; GLA, 2016). With peak rainfall intensity projected to increase by 40 percent by the end of the century (Environment Agency, 2020), the integration of trees in Sustainable Drainage Systems (SuDS) offers the greatest potential for flood prevention in urban centres (GLA, 2016). Support comes from a range of research finding canopies intercept 15-60 percent of gross precipitation (Rahman & Ennos, 2016); root penetration improves compacted subsoil permeability (Bartens, *et al*., 2008); soil cell systems increase the availability of soil for optimal root growth (benefitting canopy growth for enhanced interception) and infiltration (GreenBlue Urban, 2015). In London the amount of annual runoff prevented by trees is 3.4 million cubic metres, having a value in 2015 of £1.5 million (Rogers, *et al*., 2015).
- **Carbon**: London's trees currently store 2.4m tonnes of carbon in plant tissue, net annual sequestration is estimated at 65,500 tonnes (Edmondson, *et al*., 2014). In the Government's carbon valuation method this represents savings of £142 million and £3.93 million respectively (ibid). These figures will increase as trees mature, canopy cover increases and the future price of carbon rises (Department for Business, Energy & Industrial Strategy, 2019).
- **Nature**: Urban trees support biodiversity and conservation as a green corridor, habitat and food source for wildlife, including keystone pollinators (Hausmann, *et al*., 2015). London's three most common species, *Acer pseudoplatanus*, *Quercus robur* and *Betula pendula* are associated with 43, 423 and 334 species of insect respectively (Southwood, 1961, re-analysed by Kennedy & Southwood, 1984, cited in Rogers, *et al*., 2015). While this conveys their significance to biodiversity, the data is relatively old and updated research would improve current understanding.
- **Physical and mental health**: Access to urban greenspace incentivises more consistent and sustained exercise than equivalent indoor activities (Bodin, *et*

al., 2003, cited in Bell, *et al*., 2008; Cameron & Blanuša, 2016). Views of trees and walks through them have been repeatedly shown to promote feelings of relaxation, increase productivity and reduce recovery times for hospital patients (Ulrich, 1984; Wolf, 2004; Roloff, 2016). In Hong, *et al*., (2019) visitors of urban greenspace expressed higher levels of life satisfaction regardless of visit frequency or duration, but light and non-users reported lack of trees as a deterrent.

- **Education**: Urban trees are an educational resource (Gordon & Shirley, 2002) and exposure to urban greenspace fosters more positive perceptions of nature, especially in young people (Bixler, *et al.*, 2002, cited in Bell, *et al*., 2008); it would be worth nurturing this perception to ensure stewardship of the tree resource in the future.

The full range of benefits is extensive (table 6). The ecosystem services of London's trees are conservatively estimated to be worth £133 million per year, worth £43.3 billion in amenity value, with a replacement cost of £6.12 billion (Rogers, *et al*., 2015). As these values relate to London's 8.42 million trees, of which 700,000 are street trees it can be extrapolated that a proportionate value for street trees is £11 million per year and £3.6 billion in amenity. By comparison, the Greater Manchester iTree Eco study of 2018 (Manchester City Council, 2017; cityoftrees.org.uk, 2018) estimated the annual value of its 11.3 million trees to be worth £33.3 million; extrapolating this to Manchester's 80,000 street trees proposes a value of £233,100 per annum.

Further study is required to understand the relative value of street trees as it is likely they are outperforming other trees in some respects, while underperforming in others. For example, local air quality improvement from tree planting can be substantially more impactful on urban streets due to increased removal of pollutants than in less trafficked areas (Pugh, *et al*., 2012).

Table 6: Ecosystem services index (LUFP, 2020, p. 10).

Climate change contributions	Countering climate change	• Trees remove CO_2 to create a carbon sink • Trees provide significant low-carbon options for building and energy
	Tempering severe weather	• The capacity of trees to attenuate heavy rains and floodwater slows run-off and renders Sustainable Urban Drainage Systems more effective
	Moderating temperatures	• The ability of trees to evaporate water, reflect sunlight and provide shade combine to cut the 'urban heat-island' effect
Environment advantages	Valuable aesthetic contributions	• More attractive landscape • Eye-sores hidden • Greener more natural • Linking town to country
	Cutting soil erosion	• Preserves the valuable soil resource and keeps carbon locked in
	Positive impact on water quality	• Trees act as natural filters
	Contributing to wildlife	• Increased biodiversity as countryside becomes more porous with extra links • Brings wildlife closer to people
Economic dividends	Providing profitable by-products	• Firewood/woodchip • Compost/leaf litter mulch • Renewable fuel – via coppicing • Timber • Fruit – community orchards
	Reducing greenspace maintenance costs	• Trees are much less maintenance intensive
	Contributing indirectly to local economies	• People more productive • Job satisfaction increased • Jobs created • Inward investment encouraged • Retail areas with trees perform better • Increased property values • Adds tourism and recreational revenue
Social benefits	Delivering a range of health benefits	• Cleaner air means less asthma • Lower risk of skin cancer • Quicker patient recovery times • Reduced stress • Positive impact on mental health and wellbeing • Encourages exercise that can counteract heart disease and Type 2 Diabetes
	Assisting urban living	• Improves buildings' energy efficiency and can help alleviate fuel poverty • Improved protection in winter • Increased pedestrian safety • Baffles noise • Moderated micro-climate • Increased CO_2 absorption • Reduced crime levels
	Adding to social values	• More harmonious environments • Heightened sense of pride in place • Greater community cohesion
	Offering spiritual value	• Heightened self esteem • Puts people more in touch with Nature and the seasons • Symptoms of anxiety, depression and insomnia alleviated
	Benefiting education	• Concentration increases in 'natural' classrooms • Better learning outcomes

Disservices

Equally important to understand are the undesirable outputs that can generate negative perceptions of street trees (Flannigan, 2010). These include unwanted shading, increased bird droppings in streets, excessive fruit fall, trip hazards from raised roots, pollen production and release of biogenic volatile organic compounds, the latter of which is known to increase when trees are under stress (Goodwin, 2017). Moffat (2016) suggests that a history of LAs neglecting to address these nuisances, combined with a tendency of advocates to overemphasise the benefits, has created a dissonance wherein despite considerable evidence of their value, local communities and politicians continue to undervalue urban trees.

Further undermining the positive benefits are concerns over disparities in tree cover between wealthier and more deprived areas, Heynen, *et al*., (2006, cited in Pretzsch, 2016) revealed growing inequality in access to urban green with restricted access for poorer inhabitants. This manifests in unequal distribution of benefits, as in Cameron (2016b, p. 55), "the relationship between health/well-being and local green space seems to break down in more deprived areas.” This argument equally applies to the correlation with property price increases, as in, “the more green space nearby, the higher [the] premium is” (ONS, 2019), which is most advantageous to typically hitherto privileged areas. Tree strategies in the UK are explicit in their ambition to balance this inequality by planting in areas that lack green space (Natural Resources Wales, 2014; Forestry Commission, 2014; LUFP, 2020) and the Urban Tree Challenge Fund (Forestry Commission, 2020) is prioritising planting projects in areas of deprivation.

Street tree planting project: Grey to Green

After earning a reputation for poor tree management as a result of compulsory mass street tree felling in the ‘Streets Ahead’ contract (Forestry Commission, 2019), Sheffield County Council (SCC) has won international acclaim for their commission to regenerate a neglected area of the inner city, called Grey to Green (greytogreen.org.uk, 2016; Simson, 2019). Designers, highway and services engineers, and the University of Sheffield’s Landscape Department have collaborated on the construction of a 1.6 kilometre-long streetside garden (figure 2), which has so far cost £9.2 million, covering the first two phases of a three-phase construction.

Figure 2: Before construction commenced in 2015 (left) and in summer 2019 (right) (nigeldunnett.com, 2020).

A former dual carriageway has been transformed by the planting of thirty semi-mature trees (12 *Gleditsia triacanthos* ‘Skyline’, 11 *Quercus palustris* and 7 *Cercis siliquastrum*) and ten multi-stemmed *Betula pendula*, in a series of roadside beds and bioswales, with an additional planting of sixty trees underway in phase 2 of the scheme (CEEQUAL, 2016; Birch, 2019). Visiting the site on a weekday in autumn

2019, Simson (2019) was struck by the crowds taking their lunchbreak outside. A site visit on 26th December 2019 provided further insight into the design and use of trees in comparison to nearby examples (figures 3-10**).**

Figure 3: Grey to Green trees are planted in structural soil in mixed beds and tree pits, both designed to capture surface water runoff flowing over the sunken kerb edges.

Figure 4: Bioswale beds are connected below ground to allow drainage but divided by check dams to slow the flow during severe rainstorms (left); construction of the cascade (right – nigeldunnett.com, 2020).

Figure 5: Parallel to the new planting is an example of poor design and management; ivy running wild in a bed that sheds water into the road that runs down to the River Don.

Figure 6: Trees before work commenced (left – nigeldunnett.com, 2020) have been removed leaving vacant pits (right).

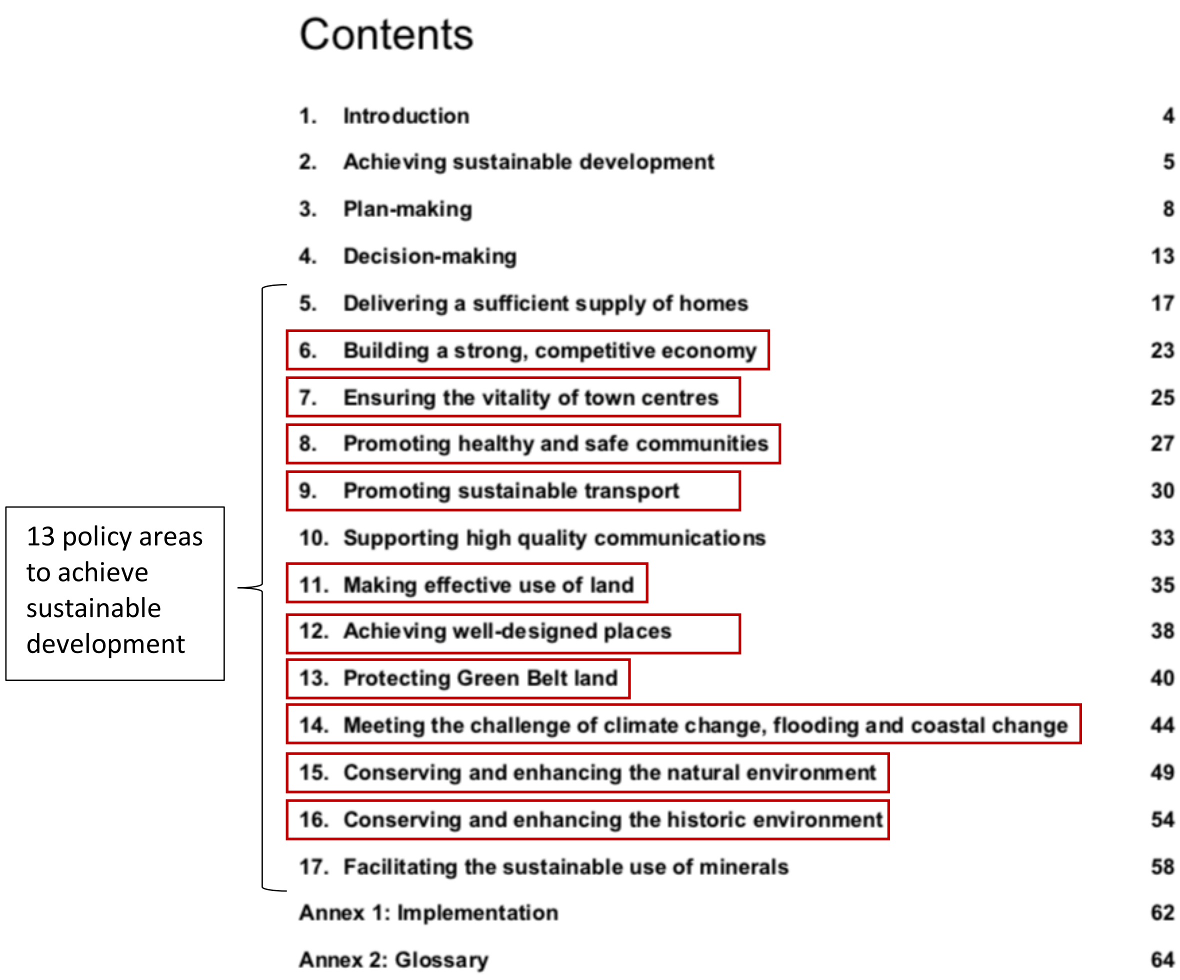
Figure 7: New beds with furniture, public art and community growing space (left); adjacent to these are four maples (*Acer* sp.) in an area enclosed on three sides, providing no incentive for seating, no route through, and the two smaller specimens are either struggling or have been replaced (right).

Figure 8: Nearby, kerbed tree diamonds placed two steps above ground level indicate low potential for stormwater interception/irrigation.

Figure 9: Nearby, large plinths will still shed run-off in rainstorms, while rooting space is limited by the depth of podium. Left image shows damaged bench beneath picturesque small pine tree (*Pinus* sp.); right images show severe pruning of a birch (*Betula* sp.). This public space (Tudor Square) was redesigned in 2010, but it is large and open enough to accommodate trees of larger stature.

Figure 10: All around the city, tree grilles are used to protect roots from compaction and allow air and water to permeate. Cases of roots pushing up, producing trip hazards, and guards damaged by heavy vehicles are common.

Through retrofitting the UK’s largest SuDS in a flood prone area, widening footpaths, creating cycle lanes, installing new public art landmarks that reveal local history, attracting new investment (Dunnett, 2020), and planting trees with known tolerances of short-term waterlogging (except *Cercis*, which is not planted in the rain gardens), drought, salt and polution (Hirons & Sjöman, 2019), the construction is a model of multifunctional urban-GI. In reference to the NPPF (2019), this innovative integration of street trees addresses ten out of the thirteen policy areas to accomplish sustainable development (figure 11).



Contents

Figure 11: Annotated contents page of the NPPF (2019).

Street tree planting practice: soil protection products

After the success of Grey to Green and drawing from iTree Eco survey data, SCC announced a new street tree strategy, aiming to increase diversity, tackle uneven distribution and involve the community (McEwan, 2020). Improved approaches may soon become the norm, not least because the UK Roads Board (2019) have committed to engage with TDAG and disseminate their guidance “across highway authorities.” Transport for London (TfL), another UF stakeholder and TDAG partner, is also dedicated to reshaping spaces in favour of trees and pedestrians over vehicles (TfL, 2017). TfL’s Leonard Circus scheme, Hackney (2014), is estimated to bring £2 million in health benefits per year using trees to slow and direct vehicles, and encourage walking and cycling. The installation of eleven semi-mature trees amongst a dense network of undergound utilities was achieved with modular soil cell products developed by another TDAG member, GreenBlue Urban (GBU) (2019).

Numerous international trials have shown the benefits of planting in soil cells as opposed to backfilling with excavated soil or planting in structural soil (GBU and Treeconomics, 2018). Compared with alternative methods, the high load-bearing capacity of soil cells allow roots to develop in a greater volume of uncompacted soil while maintaining ventilation and irrigation. This was observed at Cheshire Oaks, where the main objective of the new development was climate resilience (figures 12-15).

Figure 12: 228 new trees have been planted at urban retail outlet, Cheshire Oaks. GBU's products have been installed to overcome space restrictions, heavy traffic, high footfall and inconsistent access to water.

Figure 13: The cherry trees (*Prunus* sp.) as seen in fig. 12 all have damage to the base of the tree (left, centre), possibly caused by weather damage or physical damage (Eames, 2020, pers. comm.); to avoid physical damage from bike locks, Grey to Green trees have bike stands installed nearby (right).

Figure 14: Trees are positioned away from the enclosed car park (left, with green wall, centre) to prevent their mature canopies from trapping pollutants, as recorded on narrow street canyons where green facades are preferable solutions (Goodwin, 2017); the disservice of staining from fruit fall remains problematic (right).

Figure 15: For reference, GBU's products as seen in their brochure (left – GreenBlue Urban, 2019), and during construction of the entrance to RHS Garden Wisley, over which 1.2 million visitors walk each year (right).

GBU's products are made in the UK, so have low carbon miles attached, but are made of plastic, which has negative ecological connotations. Furthermore, the initial investment could be perceived as expensive compared to a standard street tree planting. However, the cost benefit analysis over a fifty year period, compared to a standard street tree shows a surplus using GBU's method (table 7).

Using GBU's full assembly estimate (£5000 per tree), it would cost £100 million to plant London's 20,000 vacant tree pits (LUFP, 2020), which puts the funding announcements of recent years in perspective, for example, the Urban Tree Challenge Fund at £10 million for all of England (Forestry Commission, 2020). In order to spend the available funds sensibly and attract higher investment, the scale of benefits needs to be communicated effectively, which relies on recently developed methods.

Table 7: Cost comparison profile over a fifty year period between standard street tree (01) and tree with GBU's 'RootSpace' cell system (02) (GBU and Treeconomics, 2018).

	01		02	
Item	**Street Tree - 50yrs**	**Notes**	**Tree with RSS - 50yrs**	**Notes**
Installation Costs	-£8,634.00 (-$11,665.75)	Tree replaced 4 times over the study period[1]	-£4,946.00 (-$6,679.99)	GBU planting spec[2]
Total Accumulated Benefits after 50yr period	£139.50 ($188.41)	Air pollution filtration, carbon sequestered and stormwater attenuated from the tree canopy	£8,123.00 ($10,970.80)	Air pollution filtration, carbon sequestered and stormwater attenuated from both the tree canopy and RSS
Total Maintenance	-£1,667.00 (-$2,252.17)	15% Failure Insurance (Yrs1-3), Inspection, leaf clearing and formative pruning	-£405.00 (-$547.17)	Inspection, leaf clearing, formative pruning
Removal Costs	-£1,740.00 (-$2,350.80)	End of life felling (3 times) and stump grinding	£0.00 ($0.00)	Still growing at 50 years
Net Life Cycle Cost	-£11,901.50 (-$16,078.99)		£2,772.00 ($3,743.63)	

01.
Costs include supply, delivery, installation, tree guard and tree grille, warranty, traffic management and watering. Materials such as tree grille and guard were considered reusable in subsequent tree replacement.

02.
Includes below-ground anchoring, sturdier metal guard, watering tube, aeration system, 25m^3 (885 ft^3) load-bearing cellular system complete with soil, root director, twin walled load bearing geonet and a surface opening with tree grate or permeable rubber surround.

Quantification of benefits

Monetising the value of urban trees has become fundamental in advocating their importance in the political arena (Goodwin, 2017; James, 2020, pers. comm.). Providing a suite of open-source, peer-reviewed software, iTree was developed by the USA Forest Service in 2006 (itreetools.org, 2020a). The value of London's UF was partly measured using iTree Eco, their flagship tool for analysing the structure and composition, functions, benefits and threats of tree populations. The software assesses the value of regulating services, accompanied by a risk analysis based on the structural value (for example, appraisal of tree ownership, age distribution and diversity) and susceptibility to attack from pest and disease.

To quantify the amenity value, an alternative system, Capital Asset Valuation for Amenity Trees (known as CAVAT) is the predominant method used in the UK (Doick, *et al*., 2018). Originally developed between 1998-2003, it was adopted by the LTOA in 2006 and was employed for the amenity valuation of London's UF. The method aims to render the intangible public value of trees in tangible terms; although it cannot capture the value of elusive socio-cultural services (for example, contribution to social cohesion) it can elucidate the relationship between a tree's attributes and the local community. This is achieved in seven steps, first by calculating the tree's base value, which is derived from a formula developed in the USA as a means of calculating replacement costs for trees that are larger than commonly available replacements (LTOA, 2020). This is adjusted against several factors, including the size of population that could come into contact with the tree, its location and accessibility, its health, site suitability and life expectancy.

The appraisal skills involved in CAVAT require experience and expert arboricultural knowledge, yet variations remain likely due to subjective judgements (Price, 2020). iTree's simplicity of design and free online learning tools mean participants can be relatively amateur, hence the collection of field data in London by volunteers (Rogers, *et al*., 2015). The latter is an approach that should be encouraged, as community involvement in research, known as citizen science, has been shown to have positive consequences, enhancing education, civic pride and sense of ownership, also linking to reduced crime levels and better aftercare for newly planted trees (Dickinson, *et al*., 2012; UFWACN, 2016).

Both tools discussed provide values for different subsets of benefits, which have been used consistently for over a decade to help LAs value urban trees as assets, not liabilities. Being able to estimate the annual financial benefit of ecosystem services (as in iTree) and amenity value (as in CAVAT) is beneficial in achieving fair and appropriate compensation fees when trees are damaged or removed without authorisation, and in defending their retention in design proposals (Doick, *et al*., 2018). In the design stages of a recent development at Elephant Park, Southwark, CAVAT was used to defend the retention 30 percent of existing trees and enabled the planting of 1250 new trees (TDAG, 2019b).

Other valuation methods are available, many having built on Helliwell's visual amenity assessment (1967) and improvements are likely to develop as stakeholders collaborate with environmental economists. What they all have in common is a shared understanding that economic valuations provide the basis for political decision-making and investment.

Significance of canopy cover

Valuation tools have assisted asset management through establishing baseline data from which improvements can be targeted and measured, for example, increasing tree canopy cover (TCC). TCC data informs urban tree management objectives and helps shape policy (UFWACN, 2018; Doick, *et al*., 2019). TCC simply conveys the amount of existing tree cover (area covered by leaves, stems and branches) and to what extent it could potentially be expanded (itreetools.org, 2020b). It reduces all of the known services and benefits of urban trees into an accessible metric, able to communicate to a wide audience the positive effects of the urban forest.

In a study of TCC in 283 cities and towns in England, referencing research of Scottish and Welsh cities, the mean TCC was found to be 16.4 percent in England, 17.9 percent in Scotland and 16.3 percent in Wales (Doick, *et al*., 2019). The researchers concluded their study by recommending further investigation to decide what should be an effective level of TCC for cities to target, and within what timeframe. To partly answer those questions, in terms of climate change adaptation, Gill, *et al.*, (2007) demonstrated that a 10 percent increase in tree cover in high-density areas would mitigate a future climate scenario based on a 4^{o}C temperature increase up to the year 2080. Since TCC in Greater London and Greater Manchester is roughly equal at around 21% this gives credence to the GLA's target of increasing TCC by 10 percent by 2050 (GLA, 2018b).

Despite the flaws inherent in setting a generalised standard, which omits site-specific data from local baselines to available planting space and social-economic priorities, Forest Research adopted the research by Doick, *et al*., (2019) in recommending a minimum target of 20 percent for most UK urban areas, 15 percent for coastal towns, and a target for those towns and cities already with at least 20 percent cover to increase theirs by a minimum of 5 percent within 10-20 years. At least this establishes the benchmark for locations at the lower end of the TCC range (for example, Fleetwood at 3.25%) to start making urgent improvements.

Consistency to track trends

To achieve these targets, it needs to be ensured that assessment methods are consistent, since desk-based (aerial photographs, satellite images) and field-based (ocular estimates) approaches yield different results. In London the current TCC figure of 21 percent was recorded by high-resolution aerial imagery mapping (GLA & Curio Canopy, 2018). This is significantly higher than field surveys in 2005 and 2014, which measured 8.2 percent and 13.6 percent respectively, which could be explained by more accurate separation of shrub and tree canopy, and restricted access to private gardens, where 20 percent of London's UF is located (Rogers, *et al*., 2015; LUFP, 2020). However, it is consistent with surveys of 2012 (21.9%) and 2013 (19.5%) that followed similar desk-based methodologies. Greater Manchester's iTree Eco field survey found 15.7 percent TCC (cityoftrees.org.uk, 2018), while Doick, *et al*., (2019) found it to be 21.1 percent using desk-based iTree Canopy.

Recent research maintains sufficient statistical confidence in desk-based approaches to purely quantify TCC as opposed to the more comprehensive, yet more expertise-dependent, expensive and time-consuming field-based approaches (Doick, *et al*., 2019). Therefore, Forest Research promotes iTree Canopy to authorities beginning to quantify their UF, advising to check progress every five years (UFWACN, 2018; itreetools.org, 2020b). Consistency is vital for future understanding of nationwide TCC trends, which until recently have been difficult to determine because of contrasting methodologies, notably the increase to a mean of 16.4 percent TCC in England (Doick, *et al*., 2019) from 8.18 percent recorded in 2008 (Britt & Johnston, 2008); both analysed aerial photographs but the earlier study decided to exclude urban woodlands, which cover 8 percent of London's land area alone (LUFP, 2020).

Britt and Johnston looked at the percentage of TCC comprised of street and roadside trees, with 14 percent recorded in London, a metric that Doick, *et al*., (2019) neglected to repeat. *Chainsaw massacre: A review of London's street trees* (London Assembly, 2007) highlighted a loss of TCC in a third of London boroughs between 2002-07 and a marginal net gain of trees overall undermined by the replacement of mature broadleaf trees with smaller, shorter-lived varities. Elsewhere, Wales' world-first country-wide urban canopy cover survey ascertained a decline in 55 towns and cities between 2006-09 (Natural Resources Wales, 2014). This sparked new tree planting initiatives conditional on the results of follow up site visits, “ground-truthing” (ibid, p. 104), to confirm the feasibility and suitability of available spaces identified in aerial photographs. However, TCC is only one consideration when assessing the condition of the UF.

Resilience: diversity

Alongside measuring the quantity it is important to address a range of criteria that constitute its quality, from age and species distribution and diversity, to health and suitability for location. Increasing TCC without care for these factors weakens the UF’s potential for benefit delivery and its capacity for resilience thus jeopardising the success of planting projects (Hale, *et al*., 2015).

Studying ways in which to build resilience against increased biotic and abiotic threats as a result of the climate crisis, researcher and senior lecturer in arboriculture Andy Hirons (Hirons, 2019) laments the frequent practice of planting trees that have performed reliably in the past rather than making decisions based on foresight, resulting in a “fundamental lack of diversity, particularly within our street tree populations.” This could explain the current situation in London where the ten most common species make up approximately 50 percent of the total tree population (Rogers, *et al*., 2015). Hirons observes an historic lack of vision, referencing the book, *Shade-trees in Towns and Cities*, one of the earliest species selection guides for urban planners, written in response to the prevalence of urban monocultures (Solotaroff, 1911). Hirons’ tree species selection database (2019) is one of many intending to help to simplify the process for designers and planners (citree.de, 2015; Hirons & Sjöman, 2019; Sacre, 2019). This wealth of guidance may inadvertently contribute to poor choices or wilful ignorance as planners report being “frequently overwhelmed” [by the abundance of information] linked to the plantation of trees” (Gillner, *et al*., 2016, p. 196). However, they are an essential tool for selecting species suitable for future climate scenarios.

The risk of low species diversity is increased susceptibility to attack from pests, diseases and abiotic factors, for example stress responses to elevated temperatures and drought. Responding to the millions of city trees lost to Dutch elm disease, geneticist Frank Santamour (1990) proposed a system whereby outbreaks of existing and new threats could be minimised, which has been adopted by many UK urban foresters (Forest Research, 2018). The "10-20-30 formula" (Santamour, 1990) proposes that urban tree populations should be comprised of no more than 10 percent of any single species, 20 percent of any single genus, and 30 percent of any single family. Krabel (2016) points out that this rule neither specifies area size, nor discerns between urban locations (for example, parks versus roadsides), but still has value to planners initially trying to increase diversity.

Santamour's rule also fails to account for the importance of different species; London's iTree Eco survey recorded 126 species, none of which exceed the 10 percent maximum, yet if a disease such as canker stain of plane (*Ceratocystis platani*) were to cause the destruction of Greater London's 121,000 iconic plane trees (*Platanus* x *hispanica*), which represent only 1.43 pecent of the population, they would cost an estimated £3.9 billion to replace (adjusted for inflation from Rogers, *et al*., 2015). This is due to the 5.7 percent of TCC and 6 percent of stored carbon that they embody. In a UK-wide survey of large-stature urban trees, Hand, *et al*., (2019a) ranked the most common species in order of ecosystem services provision, which illustrates how important London plane is to the rest of the UK (table 8).

Table 8: Twelve commonest large-stature trees to UK towns and cities, ranked in order of provision of four essential ecosystem services, annotated to illustrate the prominence of London plane (Hand, *et al*., 2019a).

Rank	Carbon storage	Gross carbon sequestration	Avoided run-off	Pollution removal
1	Oak spp.	Oak spp.	London plane	London plane
2	London plane	English elm#	English elm#	English elm#
3	Beech	London plane	Oak spp.	Oak spp.
4	Sycamore	Beech	Wych elm	Wych elm
5	Ash	Sycamore	Beech	Beech
6	English elm#	Holm oak	Sycamore	Sycamore
7	Holm oak	Ash	Lime spp.	Lime spp.
8	Wych elm	Wych elm	Norway maple	Norway maple
9	Norway maple	Norway maple	Ash	Ash
10	Lime spp.	Lime spp.	Holm oak	Holm oak
11	Scots pine	Scots pine	Scots pine	Scots pine
12	Leyland cypress	Leyland cypress	Leyland cypress	Leyland cypress

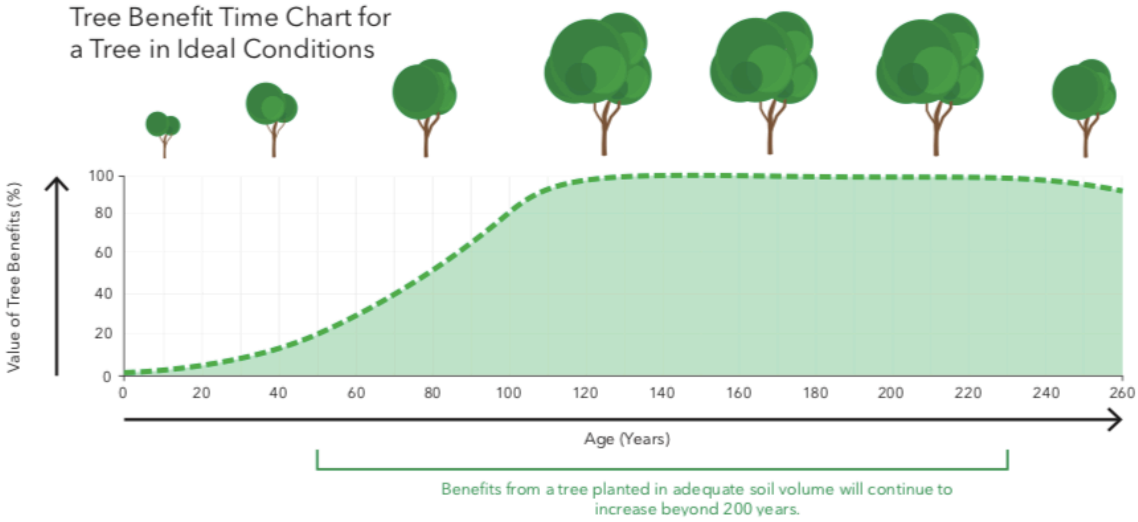
based on simulated trees due to the lack of mature trees in the field dataset

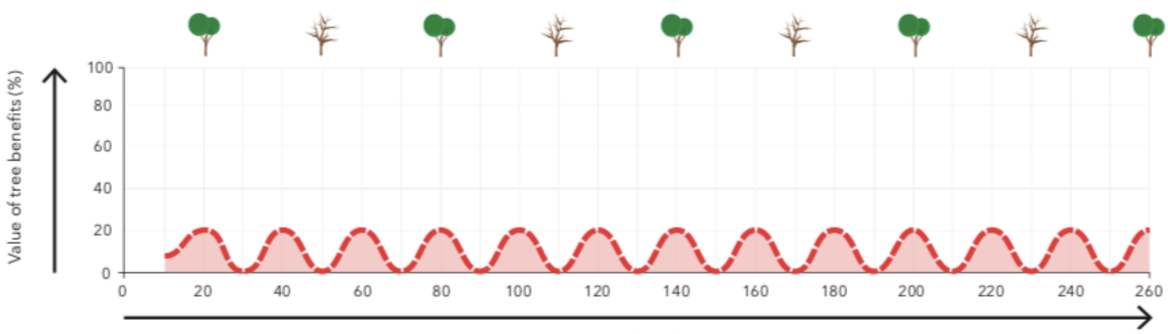
Age profile

The other part of the resilience equation is age profile. Britt and Johnson (2008) found 85 percent of trees in the urban realm were 10-50 years old, with 50 percent between 10 to 25 years of age, which is similar to more recent research that reviewed a dataset from ten iTree Eco surveys across the UK, finding 86 percent of trees capable of attaining large stature in the under 50 age bracket (Hand, *et al*., 2019a, 2019b). Beyond fifty years the benefits of mature trees rise exponentially (London Tree Officers Association (LTOA), 2019), making a persuasive argument for GBU's soil cell and associated products, as in, developers should invest in an effective method once, rather than ineffective methods numerous times (table 9).

This age distribution betrays a failure to consistently plant enough trees over the last hundred years to ensure succession, along with an unwillingness to retain large-stature trees beyond maturity (London Assembly, 2007; Natural Resources Wales, 2014). Dandy (2010, cited in Hand & Doick, 2019) recognised the relative ease of acquiring permission for tree removal as opposed to planting or protection; this predates the widespread use of economic valuation models, yet was repeated anecdotally by members of TDAG (Sacre, 2019, pers. comm.; James, 2020, pers.comm.). Meanwhile the failure of many newly planted urban trees to reach maturity is a result of high mortality rates at the juvenile stage of development due to poor selection, improper planting leading to physical and drought stress, and lack of maintenance (Fay, 2007; Rust, 2016; Hand & Doick, 2019).

Table 9: The value of benefits ascends parabolically when trees reach 50-60 years, whereas trees that fail and need to be replanted never fulfil potential (treeconomics.co.uk, 2018).





Minimise mortality, manage to maturity

Further investigation is required to find whether it is cost that is prohibiting councils from enforcing best planting practice, or if it is a result of the planning system, or a failure of communication. The probable answer is a combination of all three. Proposing a new guide for TDAG, Rose (2019, pers. comm.) believes the complexity of tree planting information needs to be reduced to a simple set of regulations, enabling planning authorities to require minimum tree pit soil volumes and stormwater irrigation design on all design proposals. In the majority of cases, Rose argues, street trees continue to be planted in poorly designed pits (figure 16) and calls this “a monumental failure of the landscape industry.” Schemes such as in Sheffield, Hackney and Cheshire are celebrated examples of design, exceptions to the rule of planting without regard for access to water, air and soil, which has resulted in a contemporary mortality rate average of 50 percent within 7-11 years (Hilbert, *et al*., 2019). This marks a decline since Britt & Johnston (2008) found 23 percent of newly planted trees on UK urban highways died during the establishment phase.

More examination is required to appraise the full extent and quality of current street tree planting projects across the UK. A continuous form of field and desk-based evaluation should be undertaken to ensure successful innovations are shared between projects and lessons learnt from failures.

Figure 16: Inadequate tree pits, such as these diamonds, are still a common sight in the UK, where the only available water is that which lands directly on the grille, aeration is inhibited, and the restricted soil volume becomes easily compacted. Such trees will not fulfil their potential.

Conclusions

Since the turn of the twenty-first century, hastened by the climate emergency, the benefits provided by urban trees have been continually reappraised resulting in a wealth of research that has directly influenced government policy. Interpretation of policy remains subjective, allowing substandard practices to persist despite knowledge of the importance of proper planting and access to best practice guidance, for example publications by the collaborative forum, TDAG (2012, 2014, 2019a, 2019b).

Increased street tree planting promises to provide some of the greatest climate crisis mitigation effects and human health, economic and environmental benefits, but only with long-term strategic planning and cross-sector, multidisciplinary cooperation can their full potential be realised.

Further work is required to bring stakeholders together and consolidate the abundance of information in an organised, accessible and practical package, and to incentivise heavier investment in urban planting by means of greater application and publication of valuation methods. To ensure the ambitious objectives of street trees are delivered, this guidance should become enforceable by law.

Bibliography

Akbari, H., 2005. *Potentials of urban heat island mitigation.* [Online]
Available at:
https://www.researchgate.net/publication/254744057_Potentials_of_urban_heat_island_mitigation
[Accessed 17 May 2020].

Auch, E., Pohris, H. & Biernath, M., 2016. Urban woods for relaxation and inspiration. In: A. Roloff, ed. *Urban Tree Management.* Chichester: John Wiley & Sons, pp. 247-261.

Bartens, J. et al., 2008. Can Urban Tree Roots Improve Infiltration Through Compacted Subsoils for Stormwater Management. *Journal of Environmental Quality,* 37(6), pp. 2048-2057.

Bell, S. et al., 2008. *Greenspace and quality of life: A critical review.* [Online]
Available at:
https://www.researchgate.net/publication/286782973_Greenspace_and_quality_of_life_A_critical_review
[Accessed 20 May 2020].

Birch, A., 2019. *Work Begins on £5.8m Grey to Green Phase 2.* [Online]
Available at: https://www.rmcmedia.co.uk/vibe/food-and-drink/article/Work-begins-on-58m-Grey-to-Green-Phase-2
[Accessed 1 May 2020].

Britt, C. & Johnston, M., 2008. *Trees in Towns II,* London: Department for Communities and Local Government.

Buranyi, S., 2019. *The air conditioning trap: how cold air is heating the world.* [Online]
Available at: https://www.theguardian.com/environment/2019/aug/29/the-air-conditioning-trap-how-cold-air-is-heating-the-world
[Accessed 17 May 2020].

Cameron, R. W., 2016a. Environmental Horticulture: Benefits and Impacts. In: R. W. Cameron & J. D. Hitchmough, eds. *Environmental Horticulture.* Wallingford: CABI, pp. 9-42.

Cameron, R. W., 2016b. Green Space and Well-Being. In: R. W. Cameron & J. D. Hitchmough, eds. *Environmental Horticulture.* Wallingford, Oxfordshire: CABI, pp. 43-74.

Cameron, R. W. F. & Blanuša, T., 2016. Green infrastructure and ecosystem services – is the devil in the detail?. *Annals of Botany,* 118(3), pp. 377-391.

CEEQUAL, 2016. *Grey to Green: Phase 1.* [Online]
Available at: https://www.ceequal.com/case-studies/grey-to-green-phase-1/
[Accessed 1 May 2020].

Central Intelligence Agency, 2019. *The World Factbook.* [Online]
Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html
[Accessed 20 December 2019].

citree.de, 2015. *Woody species for urban spaces.* [Online]
Available at: https://citree.de/?language=en
[Accessed 1 May 2020].

cityoftrees.org.uk, 2018. *Largest i-Tree Eco survey in UK highlights the £33million annual value of Greater Manchester’s trees to the economy & that 1million trees are at risk.* [Online]
Available at: https://www.cityoftrees.org.uk/news/largest-i-tree-eco-survey-uk-

highlights-£33million-annual-value-greater-manchester's-trees
[Accessed 31 May 2020].
Committee of Public Accounts, 2006. *Enhancing urban green space.* [Online]
Available at:
https://publications.parliament.uk/pa/cm200506/cmselect/cmpubacc/1073/1073.pdf
[Accessed 1 May 2020].
Costanza, R. et al., 1997. The value of the world's ecosystem services and natural capital. *Nature,* 387(15 May), pp. 253-260.
Costanza, R. et al., 2014. Changes in the global value of ecosystem services. *Global Environmental Change,* 26(May), pp. 152-158.
Department for Business, Energy & Industrial Strategy, 2019. *Updated short-term traded carbon values.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794186/2018-short-term-traded-carbon-values-for-appraisal-purposes.pdf
[Accessed 31 May 2020].
Department for Environment, Food and Rural Affairs, 2020. *Environment Bill.* [Online]
Available at: https://publications.parliament.uk/pa/bills/cbill/58-01/0009/20009.pdf
[Accessed 26 May 2020].
Dickinson, J. L. et al., 2012. The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment,* 10(6), pp. 291-297.
Doick, K. J. et al., 2016b. *Introducing England's urban forests.* [Online]
Available at:
https://www.london.gov.uk/sites/default/files/gi_007_introducing_the_urban_forest.pdf
[Accessed 26 May 2020].
Doick, K. J. et al., 2019. *The Canopy Cover of England's Towns and Cities:baselining and setting targets to improve human health and well-being.* [Online]
Available at: https://www.charteredforesters.org/wp-content/uploads/2019/01/Doick-et-al_Canopy-Cover-of-Englands-Towns-and-Cities_revised220317_combined.pdf
[Accessed 20 May 2020].
Doick, K. J. et al., 2018. CAVAT (Capital Asset Value for Amenity Trees): valuing amenity trees as public assets. *Arboricultural Journal,* 40(2), pp. 67-91.
Doick, K. J., Peace, A. & Hutchings, T. R., 2016a. *Keeping London a Cool Place to Be: The Role of Greenspace.* [Online]
Available at: https://www.charteredforesters.org/wp-content/uploads/2016/11/TPBEII-Paper-Doick-01.pdf
[Accessed 17 May 2020].
DollarTimes, 2019. *Inflation Calculator: The Changing Value of a Dollar.* [Online]
Available at: https://www.dollartimes.com/inflation/
[Accessed 30 December 2019].
Dunnett, N., 2020. *Grey to Green.* [Online]
Available at: https://www.nigeldunnett.com/grey-to-green-2/
[Accessed 1 May 2020].

Edmondson, J. L. et al., 2014. *Urban Tree Effects on Soil Organic Carbon.* [Online] Available at: https://www.researchgate.net/publication/263739658_Urban_Tree_Effects_on_Soil_Organic_Carbon [Accessed 1 May 2020].

Environment Agency, 2013. *Rainfall runoff management for developments,* London: Department for Environment, Food & Rural Affairs.

Environment Agency, 2020. *Flood risk assessments: climate change allowances.* [Online] Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#adaptive [Accessed 26 May 2020].

Environment, Transport and Regional Affairs Committee, 1999. *Town and Country Parks.* [Online] Available at: https://publications.parliament.uk/pa/cm199899/cmselect/cmenvtra/477/47706.htm [Accessed 26 May 2020].

European Commission, 2007. *Adapting to climate change in Europe – options for EU action.* [Online] Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52007DC0354 [Accessed 26 May 2020].

European Commission, 2011a. *Roadmap to a Resource Efficient Europe.* [Online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0571 [Accessed 29 December 2019].

European Commission, 2011b. *Our life insurance, our natural capital: an EU biodiversity strategy to 2020.* [Online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN [Accessed 29 December 2019].

European Commission, 2013. *Green Infrastructure (GI) — Enhancing Europe's Natural Capital.* [Online] Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:d41348f2-01d5-4abe-b817-4c73e6f1b2df.0014.03/DOC_1&format=PDF [Accessed 29 December 2019].

European Commission, 2018. *Developments and Forecasts on Continuing Urbanisation.* [Online] Available at: https://ec.europa.eu/knowledge4policy/foresight/topic/continuing-urbanisation/developments-and-forecasts-on-continuing-urbanisation_en [Accessed 30 December 2019].

European Environment Agency, 2017. *What is green infrastructure?.* [Online] Available at: https://www.eea.europa.eu/themes/sustainability-transitions/urban-environment/urban-green-infrastructure/what-is-green-infrastructure [Accessed 29 December 2019].

European Parliament and Council of the European Union (EU), 2013. *Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits*

of our planet'. [Online]
Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013D1386
[Accessed 30 December 2019].

Fay, N., 2007. *Defining and Surveying Veteran and Ancient Trees.* [Online]
Available at:
https://webcache.googleusercontent.com/search?q=cache:mPgEhCaEWn4J:https://www.treeworks.co.uk/downloads/publications/DEFINING_AGE_AND_SURVEYING_VETERAN_AND_ANCIENT%2520TREESa.pdf+&cd=3&hl=en&ct=clnk&gl=uk&client=safari
[Accessed 31 May 2020].

Flannigan, J., 2010. *An investigation of residents' relationships with street trees in southwest England.* [Online]
Available at: http://www.open-access.bcu.ac.uk/4913/1/2010_Flannigan_531564.pdf
[Accessed 26 May 2020].

Food and Agriculture Organization of the United Nations (FAO), 1993. *The Potential of Urban Forestry in Developing Countries: A Concept Paper,* Rome: Forestry Department, Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization of the United Nations (FAO), 2018. *Greener, healthier and happier cities for all: a Call for Action.* [Online]
Available at: https://www.wfuf2018.com/public/file/call_for_action_Long-Version.pdf
[Accessed 5 January 2020].

Forest Research, 2018. *Urban Tree Manual.* [Online]
Available at: https://www.forestresearch.gov.uk/tools-and-resources/urban-tree-manual/
[Accessed 1 May 2020].

Forestry Commission, 2010. *The case for trees in development and the urban environment.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/718033/eng-casefortrees.pdf
[Accessed 5 January 2020].

Forestry Commission, 2014. *The Urban Forest: How trees and woodlands can improve our lives in our towns and cities.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706814/FCURBANFORESTA44PP.PDF
[Accessed 6 January 2020].

Forestry Commission, 2019. *Sheffield Tree Felling Investigation Executive Summary.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/818606/190719_Sheffield_tree_felling_Executive_Summary.pdf
[Accessed 1 May 2020].

Forestry Commission, 2020. *Urban Tree Challenge Fund.* [Online]
Available at: https://www.gov.uk/guidance/urban-tree-challenge-fund
[Accessed 26 May 2020].

Gillner, S., Hofmann, M., Tharang, A. & Vogt, J., 2016. Criteria for species selection: Development of a database for urban trees. In: A. Roloff, ed. *Urban Tree Management.* Chichester: John Wiley & Sons, pp. 196-210.

Gill, S. E., Handley, J. F., Ennos, A. R. & Pauleit, S., 2007. Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment,* 33(1), pp. 115-133.

Goodwin, D., 2017. *The Urban Tree.* Abingdon, Oxon: Routledge.

Gordon, C. & Shirley, P., 2002. *All Things to All People – Parks and Semi-Natural Open Spaces in 21st Century Britain.* [Online]
Available at:
http://www.ukmaburbanforum.co.uk/docunents/papers/parks_Gordon.pdf
[Accessed 30 May 2020].

Greater London Authority (GLA) & Curio Canopy, 2018a. *London Tree Canopy Cover.* [Online]
Available at: https://maps.london.gov.uk/canopy-cover/
[Accessed 20 May 2020].

Greater London Authority (GLA), 2016. *London Sustainable Drainage Action Plan,* London: Greater London Authority.

Greater London Authority (GLA), 2018b. *London Environment Strategy.* [Online]
Available at:
https://www.london.gov.uk/sites/default/files/london_environment_strategy_0.pdf
[Accessed 26 May 2020].

GreenBlue Urban (GBU) and Treeconomics, 2018. *Street Tree Cost Benefit Analysis,* Bodiam: GreenBlue Urban.

GreenBlue Urban, 2015. *The importance of urban trees in stormwater management.* [Online]
Available at: https://www.greenblue.com/gb/the-importance-of-urban-trees-in-stormwater-management/
[Accessed 26 May 2020].

GreenBlue Urban, 2016a. *Benefits of Urban Trees: A guide by GreenBlue Urban.* [Online]
Available at: https://www.greenblue.com/wp-content/uploads/2016/05/Benefits-of-Urban-Trees.pdf
[Accessed 29 December 2019].

GreenBlue Urban, 2016b. *Health Benefits of Urban Trees.* [Online]
Available at: https://www.greenblue.com/wp-content/uploads/2016/05/Health-Benefits-of-Urban-Trees.pdf?gator_td=PVcFBqtikp%2buyvghkoEw2cbNpTk9cOrAVztORDYfCQw%3d
[Accessed 29 December 2019].

GreenBlue Urban, 2019. *Leonard Circus – Shared Space.* [Online]
Available at: https://www.greenblue.com/gb/case-study/leonard-circus-shared-space/
[Accessed 31 May 2020].

GreenBlue Urban, 2019. *RootSpace® Pavement Support System.* [Online]
Available at: https://www.greenblue.com/wp-content/uploads/2019/08/RootSpace-Product-Overview-2019.pdf?gator_td=NPj2uNKeyXsq4B23co7DwJGNT0UobiPcg3Cxz55ilP0%3d
[Accessed 31 May 2020].

Greenhalgh, L. & Worpole, K., 1995. *Park Life: Urban Parks and Social Renewal,* London: Demos.

Greenhalgh, L. & Worpole, K., 1996. *People, Parks & Cities: A Guide to Current Good Practice in Urban Parks: a Report for the Department of the Environment,* London: H.M. Stationery Office.

greytogreen.org.uk, 2016. *Grey to Green, Sheffield – An Introduction.* [Online]
Available at: http://www.greytogreen.org.uk/index.html
[Accessed 1 May 2020].

Hale, J. D. et al., 2015. Delivering a Multi-Functional and Resilient Urban Forest. *Sustainability,* 7(4), pp. 4600-4624.

Hand, K. L. & Doick, K. J., 2019c. *Understanding the role of urban tree management on ecosystem services,* Edinburgh: Forest Research.

Hand, K. L., Doick, K. J. & Moss, J. L., 2019a. *Ecosystem services delivery by large stature urban trees,* Edinburgh: Forest Research.

Hand, K. L., Doick, K. J. & Moss, J. L., 2019b. *Ecosystem services delivery by small and medium stature urban trees,* Edinburgh: Forest Research.

Hausmann, S., Petermann, J. S. & Rolff, J., 2015. Wild bees as pollinators of city trees. *Insect Conservation and Diversity,* 9(2), pp. 1-11.

Helliwell, D. R., 1967. The Amenity Value of Trees and Woodlands. *Arboricultural Association Journal,* 1(5), pp. 128-131.

Hilbert, D. R. et al., 2019. Urban Tree Mortality: A Literature Review. *Arboriculture & Urban Forestry,* 45(5), pp. 167-200.

Hirons, A., 2019. *RHS John MacLeod Annual Lecture series: The environmental and health benefits of trees.* [Online]
Available at:
https://www.youtube.com/watch?v=mtmxPva8c0U&list=PLXEVpDvKn91y9imURqRw4Yghr3M-36f2u
[Accessed 1 May 2020].

Hirons, A. & Sjöman, H., 2019. *Tree Species Selection for Green Infrastructure (Issue 1.3).* [Online]
Available at:
http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_treespeciesguidev1.3.pdf
[Accessed 1 May 2020].

Howard, L., 1833. *The Climate of London.* 2nd ed. Dublin: SATTAL.

Huang, J. Y., Black, T., Jassal, R. & Lavkulich, L. M., 2017. Modelling rainfall interception by urban trees. *Canadian Water Resources Journal,* pp. 1-13.

Institute of Chartered Foresters, 2020. *Trees, People and the Built Environment 4.* [Online]
Available at: https://www.charteredforesters.org/event/trees-people-built-environment-4/
[Accessed 1 May 2020].

International Climate Emergency Forum, 2020. *ICEF - Governments emergency declaration spreadsheet.* [Online]
Available at: https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/
[Accessed 26 May 2020].

International Energy Agency, 2018. *Air conditioning use emerges as one of the key drivers of global electricity-demand growth.* [Online]
Available at: https://www.iea.org/news/air-conditioning-use-emerges-as-one-of-the-key-drivers-of-global-electricity-demand-growth
[Accessed 17 May 2020].

International Institute for Sustainable Development, 2016. *Goal 11 - Sustainable Cities & Communities.* [Online]

Available at: https://sdg.iisd.org/sdgs/goal-11-sustainable-cities-communities/
[Accessed 6 January 2020].
itreetools.org, 2020a. *i-Tree Academy 2020 concludes.* [Online]
Available at: https://www.itreetools.org/blog/2020-i-tree-academy-training-program-begins-january-22
[Accessed 31 May 2020].
itreetools.org, 2020b. *i-Tree Canopy v7.0 Cover Assessment and Tree Benefits Report.* [Online]
Available at: https://www.itreetools.org/documents/617/Hartford_CT_i-Tree_Canopy_report_example.pdf
[Accessed 25 May 2020].
Johnston, M., 2017. *Street Trees in Britain: A History.* Oxford: Windgather Press.
Jorgensen, E., 1986. Urban Forestry in the Rearview Mirror. *Arboricultural Journal,* Volume 10, pp. 177-190.
Kniesel, B., 2016. Dust and noise reduction. In: A. Roloff, ed. *Urban Tree Management.* Chichester: John Wiley & Sons, pp. 177-184.
Krabel, D., 2016. Genetic aspects. In: A. Roloff, ed. *Urban Tree Management.* Chichester: John Wiley & Sons, pp. 211-220.
Leahy, I., 2016. *Innovations in Urban Forestry.* [Online]
Available at: https://www.americanforests.org/magazine/article/innovations-in-urban-forestry/
[Accessed 26 May 2020].
Leahy, I., 2017. *Why We No Longer Recommend a 40 Percent Urban Tree Canopy Goal.* [Online]
Available at: https://www.americanforests.org/blog/no-longer-recommend-40-percent-urban-tree-canopy-goal/
[Accessed 20 May 2020].
Leibowicz, B. D., 2017. Effects of urban land-use regulations on greenhouse gas emissions. *Cities,* Volume 70, pp. 135-152.
London Assembly, 2007. *Chainsaw massacre: A review of London's street trees.* [Online]
Available at:
https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/archives/assembly-reports-environment-chainsaw-massacre.pdf
[Accessed 20 May 2020].
London Tree Officers Association (LTOA), 2019. *The Exponential benefits of trees.* [Online]
Available at: https://www.ltoa.org.uk/news/389-the-exponential-benefits-of-trees
[Accessed 31 May 2020].
London Tree Officers Association (LTOA), 2020. *CAVAT - All Versions (Updated - January 2020).* [Online]
Available at: https://www.ltoa.org.uk/documents-1/capital-asset-value-for-amenity-trees-cavat/174-cavat-all-versions-updated-may-2015
[Accessed 31 May 2020].
Lopez, S. F. L., Sheridan, R., Benavides, H. & Maco, S., 2018. *Internationalizing Urban Ecosystem Benefits through I-Tree Eco.* Mantova, World Forum on Urban Forests.
Manchester City Council, 2017. *Manchester Tree Action Plan.* [Online]
Available at:
https://www.manchester.gov.uk/downloads/download/6838/manchester_green_and

_blue_strategy
[Accessed 20 May 2020].
Marritz, L., 2014. *Treating Trees as Actual Infrastructure.* [Online]
Available at: https://www.deeproot.com/blog/blog-entries/treating-trees-as-actual-infrastructure
[Accessed 30 December 2019].
McEwan, G., 2020. *Sheffield to draw line under past conflicts with new street tree strategy.* [Online]
Available at: https://www.hortweek.com/sheffield-draw-line-past-conflicts-new-street-tree-strategy/arboriculture/article/1677386?bulletin=breakfast-briefing&utm_medium=EMAIL&utm_campaign=eNews%20Bulletin&utm_source=20200318&utm_content=Horticulture%20Week%20Breakfast%2
[Accessed 1 May 2020].
Millennium Ecosystem Assessment Board, 2005. *Ecosystems and Human Wellbeing.* [Online]
Available at:
https://ohcea.org/OhceaModules/Ecosystem%20Health/Ecosystem%20Health%20Resources/Corrvalan_Ecosystem%20Health.pdf
[Accessed 1 May 2020].
Ministry of Housing, Communities and Local Government, 2019. *NPPF - National Planning Policy Framework,* London: Her Majesty's Stationery Office .
Moffat, A. J., 2016. Communicating the benefits of urban trees: A critical review. *Arboricultural Journal,* 38(2), pp. 64-82.
National Park City Foundation, 2019. *London is officially the world's first National Park City.* [Online]
Available at: http://www.nationalparkcity.london
[Accessed 31 May 2020].
Natural England, 2009. *Green Infrastructure Guidance,* York: Natural England.
Natural Resources Wales, 2014. *Tree Cover in Wales' Towns and Cities.* [Online]
Available at: https://naturalresources.wales/media/4123/tree-cover-in-wales-towns-and-cities-2014-study.pdf
[Accessed 1 January 2020].
Natural Resources Wales, 2016. *Town Tree Cover in Conwy County Borough,* Aberystwyth: Natural Resources Wales.
Office for National Statistics (ONS), 2015. *Urban areas in the UK.* [Online]
Available at:
https://www.ons.gov.uk/aboutus/transparencyandgovernance/freedomofinformationfoi/urbanareasintheuk
[Accessed 20 May 2020].
Office for National Statistics (ONS), 2018. *UK air pollution removal: how much pollution does vegetation remove in your area?.* [Online]
Available at:
https://www.ons.gov.uk/economy/environmentalaccounts/articles/ukairpollutionremovalhowmuchpollutiondoesvegetationremoveinyourarea/2018-07-30
[Accessed 26 May 2020].
Office for National Statistics (ONS), 2019. *Urban green spaces raise nearby house prices by an average of £2,500.* [Online]
Available at:

https://www.ons.gov.uk/economy/environmentalaccounts/articles/urbangreenspacesraisenearbyhousepricesbyanaverageof2500/2019-10-14
[Accessed 31 May 2020].

Pretzsch, J., 2016. Governance in urban forestry. In: A. Roloff, ed. *Urban Tree Management.* Chichester: John WIley & Sons, pp. 221-235.

Price, C., 2020. Considerations concerning CAVAT: what does its “tree amenity value” actually measure?. *Arboricultural Journal,* p. https://doi.org/10.1080/03071375.2020.1721957 [visited on 5 June 2020.].

Public Health England (PHE), 2020. *Review of interventions to improve outdoor air quality and public health.* [Online]
Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/795185/Review_of_interventions_to_improve_air_quality.pdf
[Accessed 26 May 2020].

Pugh, T. A., MacKenzie, A. R., Whyatt, J. D. & Hewitt, C. N., 2012. Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons. *Environmental Science & Technology,* Volume 46, pp. 7692-7699.

Rahman, M. A. & Ennos, A. R., 2016. *What we know and don’t know about the surface runoff reduction potential of urban trees.* [Online]
Available at: http://www.tdag.org.uk/uploads/4/2/8/0/4280686/what_is_known_and_not_know_stormwater_attenuation_benefits_of_urban_trees.pdf
[Accessed 26 May 2020].

Rahman, M. A. et al., 2018. Vertical air temperature gradients under the shade of two contrasting urban tree species during different types of summer days. *Science of the Total Environment,* Volume 633, pp. 100-111.

Ritchie, H. & Roser, M., 2019. *Urbanization.* [Online]
Available at: https://ourworldindata.org/urbanization#all-charts-preview
[Accessed 15 May 2020].

Rogers, K., Sacre, K., Goodenough, J. & Doick, K., 2015. *Valuing London's Urban Forest.* [Online]
Available at: https://urbantreecover.org/wp-content/uploads/2015/12/LondoniTree.pdf
[Accessed 20 May 2020].

Roloff, A., ed., 2016. *Urban Tree Management for the Sustainable Development of Green Cities.* Chichester: Wiley Blackwell.

Roser, M., 2019. *Future Population Growth.* [Online]
Available at: https://ourworldindata.org/future-population-growth#global-population-growth
[Accessed 15 May 2020].

Rust, S., 2016. Tree preservation, maintenance and repair. In: A. Roloff, ed. *Urban Tree Management.* Chichester: John Wiley & Sons, pp. 135-153.

Sacre, K., 2019. *Species selection.* [Online]
Available at: https://www.barchampro.co.uk/guide/species-selection/
[Accessed 1 May 2020].

Santamour, F. S., 1990. *Trees for Urban Planting: Diversity, Uniformity, and Common Sense.* Lisle, Illinois, Metropolitan Tree Improvement Alliance, pp. 57-66.

Searns, R. M., 1995. The evolution of greenways as an adaptive urban landscape form. *Landscape and Urban Planning,* 33(1-3), pp. 65-80.

Seo, Y., 2020. Varying Effects of Urban Tree Canopies on Residential Property Values across Neighborhoods. *Sustainability,* 12(10)(4331), pp. 1-19.

Solotaroff, W., 1911. *Shade-trees in Towns and Cities.* Cambridge, MA: J. Wiley.

Stokes, J., Miles, A. & Rodger, D., 2004. *The heritage trees of Britain and Northern Ireland.* 1st ed. London: Constable & Robinson.

sufc.org, 2020. *The trees, vegetation, and green spaces that make up America's urban forests are essential contributors to virtually every measure of public well-being..* [Online]
Available at: https://sufc.org
[Accessed 26 May 2020].

Swanwick, C., Dunnett, N. & Woolley, H., 2003. Nature, Role and Value of Green Space in Towns and Cities: An Overview. *Built Environment,* 29(2), pp. 94-106.

Town and Country Planning Association (TCPA), 2008. *The Essential Role of Green Infrastructure,* London: Town and Country Planning Association.

Town and Country Planning Association (TCPA), 2018. *What is green infrastructure?.* [Online]
Available at: https://www.tcpa.org.uk/green-infrastructure-definition
[Accessed 29 December 2019].

Transport for London (TfL), 2017. *Better Streets Delivered 2.* [Online]
Available at: http://content.tfl.gov.uk/better-streets-delivered-2.pdf
[Accessed 31 May 2020].

Trees and Design Action Group (TDAG), 2012. *Trees in the Townscape.* [Online]
Available at: http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_trees-in-the-townscape_november2012.pdf
[Accessed 1 May 2020].

Trees and Design Action Group (TDAG), 2014. *Trees in Hard Landscapes: A Guide for Delivery.* [Online]
Available at: http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_trees-in-hard-landscapes_september_2014_colour.pdf
[Accessed 1 May 2020].

Trees and Design Action Group (TDAG), 2019a. *First Steps in Air Quality for Built Environment Practitioners.* [Online]
Available at: http://epapers.bham.ac.uk/3069/1/Ferranti_etal_2019_FirstStepsAQ.pdf
[Accessed 20 May 2020].

Trees and Design Action Group (TDAG), 2019b. *First Steps in Valuing Trees and Green Infrastructure.* [Online]
Available at: http://epapers.bham.ac.uk/3226/1/TDAG_ValuingTrees%26GI_2019.pdf
[Accessed 1 May 2020].

UK Roads Board, 2019. *Minutes of 63rd meeting of the UK Roads Board meeting held on 8 November 2019 held atthe Chartered Institution of Highways and Transportation.* [Online]
Available at:
http://webcache.googleusercontent.com/search?q=cache:5tZJuXFUHkoJ:www.ukroadsliaisongroup.org/download.cfm/docid/D53E12C9-C58E-489D-

A2ADF64821516856+&cd=1&hl=en&ct=clnk&gl=uk&client=safari
[Accessed 1 May 2020].

UK Stakeholders for Sustainable Development , 2017. *What is sustainable development?.* [Online]
Available at: https://www.ukssd.co.uk/sustainable-development
[Accessed 26 May 2020].

Ulrich, R., 1984. View through a window may influence recovery from surgery. *Science,* 224(4647), pp. 420-421.

United Nations (UN), 2015. *Adoption of the Paris Agreement, 21st Conference of the Parties,* Paris: United Nations & Framework Convention on Climate Change.

United Nations (UN), 2017. *GLOSSARY OF THE HABITAT III.* [Online]
Available at: http://habitat3.org/wp-content/uploads/Habitat-III-Glossary.pdf
[Accessed 11 January 2020].

United Nations (UN), 2018. *2018 Revision of World Urbanization Prospects.* [Online]
Available at: https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html
[Accessed 20 May 2020].

Urban Forestry and Woodlands Advisory Committee Network (UFWACN), 2016. *Our Vision for a Resilient Urban Forest.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700389/urban-forest-final-v4.pdf
[Accessed 1 May 2020].

Urban Forestry and Woodlands Advisory Committee Network (UFWACN), 2018. *Tree canopy cover leaflet: Using tree canopy cover data to secure the benefits of the urban forest.* [Online]
Available at: https://www.forestresearch.gov.uk/tools-and-resources/tree-canopy-cover-leaflet/
[Accessed 1 May 2020].

Urban Green Spaces Taskforce, 2002. *Green spaces, better places,* London: Department for Transport, Local Governmnet and the Regions.

Wolf, K. L., 2004. *Public Value of Nature: Economics of Urban Trees, Parks and Open Space.* Oklahoma, Environmental Design Research Association.

Wolf, K. L., 2005. Trees in the small city retail business district: Comparing resident and visitor perceptions. *Journal of Forestry,* 103(8), pp. 390-395.

World Commission on Environment and Development, 1987. *Our Common Future,* New York: The World Commission on Environment and Development.

YouGov & ClientEarth, 2018. *ClientEarth's Climate Snapshot.* [Online]
Available at: https://www.documents.clientearth.org/wp-content/uploads/library/2018-08-20-clientearths-climate-snapshot-coll-en.pdf
[Accessed 26 May 2020].

Zabret, K. & Šraj, M., 2019. Rainfall Interception by Urban Trees and Their Impact on Potential Surface Runoff. *Clean: Soil Air Water,* 47(8).

Climate Change Act 2008, London: The Stationery Office.
Environment Bill 2020. [Online]
Available at: https://www.gov.uk/government/publications/environment-bill-2020/30-january-2020-environment-bill-2020-policy-statement [Accessed 1 June 2020].

Unpublished references

Law, A., (2019a) Field visit new entrance construction, RHS Garden Wisley, figure 15, 18th January 2019.
Law, A., (2019b) Field visit Sheffield Grey to Green, figures 3-10, 26th December 2019.
Law, A., (2020a) Field visit Cheshire Oaks retail outlet, Cheshire, figures 12-14, 1st January 2020.
Law, A., (2020b) Field visit Brooklands Centre car park, Weybridge, figure 16, 6th January 2020.
Law, A., (2020c) Field visit Smith Square, London, figure 1, 14th January 2020.
London Urban Forest Partnership, 2020. *London Urban Forest Plan (Draft version 1.0),* London: The London Urban Forest Partnership.
Thinking Outside the Pot, (2020) Sustainable landscape conference, Ashford International Hotel, Kent, 22nd January 2020.
Trees and Design Action Group, (2019c) Meeting, Vincent Square, 21st November 2019.
Trees and Design Action Group, (2020) Meeting, Vincent Square, 14th January 2020.

Personal communications

Eames, D., (2020) Derek Eames, Urban Forestry Consultant, GreenBlue Urban, email communication, 12th February 2020.
James, S., (2020) Sue James, Member, Trees and Design Action Group, meeting discussion, 14th January 2020.
Rose, B., (2019) Ben Rose, Principal Consultant, Bosky Trees, meeting discussion, 21st November 2019.
Sacre, K. (2019) Keith Sacre, Arboriculturist, Urban Forest Director and Member, Trees and Design Action Group, meeting discussion, 21st November 2019.
Simson, A. (2019) Alan Simson, Professor of Landscape Architecture and Urban Forestry, Leeds Beckett University, meeting discussion, 21st November 2019.