Chapter 1: So what have urban trees ever done for us?

> We are left in awe by the nobility of a tree, its eternal patience, its suffering caused by man and sometimes nature, its witness to thousands of years of earth's history, its creations of fabulous beauty. It does nothing but good, with its prodigious ability to serve, it gives off its bounty of oxygen while absorbing gases harmful to other living things. The tree and its pith live on. Its fruits feed us. Its branches shade and protect us. And finally, when time and weather brings it down, its body offers timber for our houses and boards for our furniture. The tree lives on.
>
> George Nakashima (American architect, woodworker and furniture maker)

1.1 INTRODUCTION

In 2008, the planet reached an important milestone. The world population, as a whole, moved from being predominantly rural to becoming mainly urban (UN Department of Economic and Social Affairs, Population Division, 2008). This trend is set to intensify, and it is predicted that by 2050, two-thirds of the world's population will be city-dwelling (UN Department of Economic and Social Affairs, Population Division, 2014). In Europe, approximately 80 per cent of the population will be living in urban areas by 2020 (European Environment Agency, 2006). Almost 90 per cent of the British population was already living in urban areas by 1991 (Denham & White, 1998), and this propensity for urban living is likely to be matched by seven other European countries by 2020 (European Environment Agency, 2006). The social and environmental implications of this are obviously enormous.

It is true that urban expansion, if adequately planned for, has the potential to improve peoples' access to health care, education, housing and other services. It is also true that we have been exploiting trees within our urban landscapes, for the benefits they provide us, since the sixteenth century. This use of trees within urban centres reached its peak with the garden city movement and workers' colonies of the mid to late nineteenth century (Lawrence, 2006), where pressure from social reformers to increase access to green open space not only helped in urban beautification, but also improved the life of city inhabitants from all social classes. Formal street tree planting formed part of this urban greening and spread rapidly from London into urban development schemes for other UK cities and commercial centres, where it was seen as a symbol of civilisation. The result of this recognition of the importance of providing city populations with street trees and access to green open space means that many of the finest examples of our existing urban trees are a legacy from the Victorian era. It is sometimes sobering to consider that the

Figure 1.1
A busy pedestrian thoroughfare, a food market, a sunny day, dappled shade from trees, what's not to love? The Southbank, London.

longevity of some of these urban trees has proved to be greater than that of the built form around them.

However, the unending development of an increasingly urban society places an ever-mounting reliance upon built infrastructures and technology to provide the services and goods required to enable that society to function efficiently. The urban heat island effect, the expansion of impermeable surfaces, the inevitable increase in the total energy consumption and the concomitant additional air pollution this creates, lead to an ever-increasing decoupling and independence from ecological systems. Somewhat perversely, it is the solar shading, surface water attenuation, air quality improvements and increased physical and mental well-being (ecosystem services) provided by these ecological systems, of which urban trees and other vegetation are part, which play such an important role in making our cities more pleasant places to be.

Designers are readily cognisant of the aesthetic qualities but infrequently of the other physical and environmental benefits and how trees can improve our mental well-being. This chapter provides an overview of how trees can be used to provide a more beautiful, comfortable, productive and liveable urban landscape. It will also investigate why, despite more trees being planted overall, we are finding fewer and fewer large species trees within our cities, typically due to conflicts during construction and the close proximity of hard, grey infrastructures. It is, after all, these larger trees that are better placed to deliver more of the environmental benefits for a greater period of time than smaller, shorter-lived species. Many of the large canopy tree species we plant have the genetic potential to survive for well over 100 years, yet the redevelopment cycle of many urban plots will be significantly less at, perhaps, 60–80 years. To realise this potential for longevity, however, we must ensure that the trees we plant establish within the site selected and are equipped with the necessary resources to grow to productive maturity.

1.2 GREEN INFRASTRUCTURE, A DEFINITION

The concept of 'green infrastructure' has gained political momentum in recent years, with much popularity among the various levels of decision-makers, from parliamentary and local politicians, government departments and agencies, through to land planning, landscape and urban design professionals. It appears to have originated in the United States from a report submitted to the Governor of Florida by the Florida Greenways Commission (Firehook, 2015). The report states that 'The Commission's mission is to create a system of greenways for Florida, a green infrastructure as carefully planned and as well funded as our built infrastructure (like electric power and transportation systems)' (Florida Greenways Commission, 1994). The linking of the two words, green and infrastructure, was intended to raise awareness that the planning of 'natural systems' must be considered on an equal basis with other traditional grey infrastructures (Firehook, 2015). More general circulation of the term followed the May 1999 publication of *Towards a Sustainable America*, produced by the President's Council on Sustainable Development. Here, the term was described thus: 'the network of open space, airsheds, watersheds, woodlands, wildlife habitats, parks, and other natural areas that provides many vital services that sustain life and enrich the quality of life' (1999).

Since then, many different people have used the term in many different ways, but however it is described, the emphasis, as with any description of an infrastructure, must be on the importance of the benefits provided for people. Mark Benedict and Edward McMahon have been instrumental in helping to define what green infrastructure is and in their book *Green Infrastructure: Linking landscapes and Communities*, they offer the following: 'An interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife' (Benedict & McMahon, 2006). They go on to emphasise 'that it is planned and managed for its natural resource values and for the associated benefits it confers' (Benedict & McMahon, 2006). A traditional conservation approach is likely to focus on environmental preservation and restoration in isolation, and this often results in conservation being antagonistic or in opposition to development. A green infrastructure approach, while acknowledging the need for residential, commercial and business development, is more strategic and co-operative. It provides a framework which enables the conservation of natural areas and the provision of additional designed green space to be identified and prioritised within planned development. In this way, land use is optimised for physical, utility and ecosystem service provision, for the benefit of all. In line with any other infrastructure, it is important to consider the fact that planning and management are part of the package. In order to safeguard open areas, green spaces, trees and woodlands, and to capitalise on the benefits provided by them, a strategic approach must be adopted with a clear, logical and achievable vision as its intended goal. It is also worth pointing out that green infrastructures should operate at all spatial scales, from urban cores out to the surrounding countryside (URBED, 2004). Without this approach, green and other open spaces can become a collection of isolated and disparate, undeveloped or abandoned sites, rather than an inter-connected system that is planned, protected, managed, and at times, restored.

Although considered fairly new, the concept of green infrastructure planning certainly is not. The American landscape architect, Frederic Law Olmstead's scheme for Boston's famous Emerald Necklace consists of a 445 hectare (1,100 acres) chain of parks and green spaces, linked together by a network of drives, rides and walks. The chain begins in the downtown area of the city and broadly cuts a sweeping arc, linking Boston Common and Boston Public Garden with Back Bay Fens, Olmstead Park, Jamaica Pond and the Arnold Arboretum, to terminate at Franklin Park, south-west of the city. The project originally started life in 1878 with the restoration of The Back Bay Fens for reasons of sanitation. The Back Bay area was originally tidal salt marsh that had become so contaminated with raw sewage and industrial effluent that it posed a significant health risk to residents of surrounding neighbourhoods. Olmstead realised that not only could it be cleaned and restored to its original salt marsh condition, but it could be used as a flood defence wetland, possibly the first of its kind to be constructed (Spirn, 1995). Beyond the restoration work, an interceptor sewer was added, as was a parkway, footpaths and horse rides to provide recreation facilities for visitors. Boston's first tram service was also constructed to service the newly created park. Collectively, these facilities and functions formed a landscape system that managed the removal of sewage, provided safeguard against flooding and accommodated the recreational needs of the people of Boston (Spirn, 1995). Green infrastructure, therefore, refers to more than the natural areas alone; it can also include constructed landscapes and facilities. The importance is that there are some ecological, social and economic benefits associated with its existence.

There is also confusion sometimes between the use of terms green infrastructure and urban forest. In the United Kingdom, the now defunct National Urban Forestry Unit defined the urban forest as: 'all the trees and woods in an urban area: in parks, private gardens, streets, around factories, offices, hospitals and schools, on wasteland and in existing woodland. Urban forestry is the planned approach to the planting and management of trees and woods in towns' (National Urban Forestry Unit, 1999). The Society of American Foresters add a little more detail to the practice of urban forestry, in *The Dictionary of Forestry*, thus: 'the art, science, and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society' (Helms, 1998)**.** The urban forest, therefore, is considered an element within green infrastructure.

1.3 DESIGNERS' TOOLKIT

In design terms, trees have always been seen as one of the urban planner's most useful tools. They can improve urban landscapes by bringing an aesthetic value, helping to soften hard surfaces, guiding and framing views and by providing a setting for buildings, helping the user and viewer to negotiate that transition from tall built forms to ground level. They can be used to help delineate spaces by introducing visual and physical separation between areas, informing a hierarchy of use. They can deflect the eye to aid circulation. They can concentrate the view to guide movement, helping to inform direction, destination and a sense of arrival. They increase visual diversity by introducing shape and form, often bringing a leafy sense of calm to a setting. They can also introduce vibrancy and excitement with some quite spectacular colour displays during otherwise dull times of the year. Despite all these aesthetic qualities they bring to the landscape, urban trees are being threatened as never before due to reduced local authority budgets, increased development pressure, public apathy and a risk-averse insurance industry.

Trees in Towns II was a research project commissioned by the Department of Communities and Local Government, which investigated the condition and management of the urban tree population in England (Britt & Johnston, 2008). The report highlighted that, on average, over 24 per cent of the local authority trees planted in public open space and 23 per cent of the trees planted along highways die before they become established. These findings have been substantiated by other later research studies (Jack-Scott, Piana, Troxel, Murphy-Dunning & Ashton, 2013; Roman, Battles & McBride, 2014) for publicly owned trees, but may even be higher than this for trees in private ownership (Jack-Scott, Piana, Troxel, Murphy-Dunning & Ashton, 2013). A contemporaneous review of London's street trees for the London Assembly, entitled

'Chainsaw Massacre' (GLA, 2007), highlighted a worrying trend in the progressive reduction of the overall tree canopy cover. Despite 48,000 trees being planted and 40,000 being removed, across London as a whole between 2002 and 2007, twelve of the thirty-three boroughs still reported a net loss in publicly owned tree stock for the same period. In many instances, large mature trees are being replaced with smaller, shorter-lived varieties (GLA, 2007). These findings were echoed by '*Trees in Towns II*', which found that what is happening in London appears to be common to other urban conurbations throughout the UK (Britt & Johnston, 2008). If these trends continue, our green infrastructure legacy, in contrast to that of our Victorian forebears, will be one of perpetual immaturity, unable to provide the ecosystem benefits we require of it (Sjöman, Hirons & Bassuk, 2015).

1.4 URBAN PLACES CAN BE TREE-HOSTILE

Unlike the natural environments to which trees have adapted, urban locations can be stressful and far from ideal; yet we still expect these hostile environments to provide the resources necessary for healthy tree growth.

A variety of conditions and factors can cause stress to urban trees; they are surrounded by buildings, often planted within a sea of impervious surfaces and subjected to reflected and radiated heat, wind funnelling and shade from sun and rain (Whitlow & Bassuk, 1988).

- Restricted root volume: Concrete kerbs, building foundations and basements, utility infrastructure, construction rubble and engineered build-up all help to restrict the amount of soil available for tree roots to explore for required water and nutrients (Lindsey & Bassuk, 1992).
- Soil compaction: In order to support engineered surfaces and structures, soils are typically required to be compacted far beyond the limit at which root penetration is prevented. Compaction also reduces the amount of pore space within the soil profile, which, in turn, restricts the movement of oxygen to the root zone and can create localised waterlogging (Craul, 1985; Lichter & Lindsey, 1994; Randrup, 1998).

Figure 1.2
The tenacity of London planes has to be admired. Despite appearing to have very little in terms of soil, water and nutrient cycling, this tree is still able to grow, somehow managing to exploit the resources it can access.

- Alkaline soil: The presence of many lime-containing materials causes the soil to become highly alkaline, limiting the amount of some important nutrients, such as iron and manganese, available to plants. The results of such soil can often be seen as yellowing foliage – chlorosis (Craul, 1985).
- Inconsistent access to water: Despite rainfall in cities being typically 5–10 per cent higher than in the rural areas, the majority of surface water, during heavy summer rain events, flows off hard surfaces, with very little being absorbed into the ground (Hoff, 2001).
- High urban temperature: The re-radiated heat from buildings, paving materials and other hard infrastructures all help to elevate the air temperature within urban centres. The higher the temperature, the more water trees lose through transpiration from their leaves (Doll, Ching & Kaneshiro, 1985; Montague & Kjelgren, 2004). This is thought to have a greater implication in the creation of water deficits in trees than a lack of available water within the root zone (Whitlow & Bassuk, 1988; Whitlow, Bassuk & Reichert, 1992).

A recent urban trend is the use of trees in the training of fighting dogs. The owners encourage their dogs to jump up and lock their mouths onto the lower branches of trees as a way to build up strength in the dog's jaws, neck and shoulders. They are also goaded into attacking tree stems and stripping bark, to encourage aggression and sharpen their teeth. It is not an uncommon sight within urban parks and inner city green spaces to see tree stems and branches stripped of their bark where they have been used to train these so-called 'weapon dogs' (Barkham, 2009). In response, local authorities are using a variety of methods to deter these practices, from bamboo, hessian and mesh wrapping to chestnut paling fencing and metal tree guards. Some local authorities are using a non-toxic, bio-degradable, foul-tasting grease, applied to tree stems and branches. Such measures make a visual impact and could be considered 'unsightly'. The London Tree Officers' Association suggests that tree protection is only one element within what should be a multi-faceted approach (LTOA, 2010). They argue that the tree damage caused by these antisocial activities is best dealt with through education and community engagement initiatives, which are run in tandem with multi-agency co-operation and law enforcement. Somewhat perversely, the Royal Society for the Prevention of Cruelty to Animals (RSPCA) reports that there are more pitbull-type dogs seized by the police in the UK now than when they were outlawed by the Dangerous Dogs Act in 1991 (RSPCA, 2011).

1.4.1 Ecosystem services and perceived disservices

There currently is much enthusiasm, both within the academic and political worlds, to foster a greater mutual understanding of the concept of ecosystem services. The term 'ecosystem services' was popularised by the Millennium Ecosystem Assessment (MA), a multi-nation initiative whose objective was to 'assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being' (Millennium Ecosystem Assessment, 2005). The MA defined ecosystem services as 'the benefits people obtain from ecosystems' (Millennium Ecosystem Assessment, 2003). These benefits were grouped under four functional headings:

- **Provisioning services** are the products obtained from ecosystems, such as food, fibre, fuel and fresh water.

- **Regulating services** are the benefits obtained from the regulation of ecosystem processes, such as air quality mitigation, climate regulation (energy reduction), storm water storage and attenuation, carbon sequestration, water treatment, biological control and pollination.
- **Cultural services** are the heritage, spiritual, social, educational, recreational and aesthetic benefits derived from ecosystems.
- **Supporting services** are those necessary for the production of all other ecosystem services and tend to be indirect or occur over a long period of time, such as nutrient recycling, primary production and soil formation (Millennium Ecosystem Assessment, 2003).

However, if suitable management strategies and environmental policy are to be made, an understanding of both the benefits and dis-benefits that urban ecosystems can provide is essential. For instance, it is not uncommon for trees in built-up areas to be perceived as a nuisance (Schroeder, Flannigan & Coles, 2006). Certainly, large trees growing close to inhabited buildings – both housing and office spaces – may cast unwanted shade, and careful consideration needs to be given to the siting of trees in such locations.

Falling leaves may be cited as the cause for blocked drains and gutters. Leaf fall coupled with wet weather may also be implicated in the disruption to the normal running of rail services due to the increase in braking distances. Network Rail claim that in 2013, 4.5 million hours of delays were caused by leaves (Network Rail). The same safety concerns could also be raised about leaves falling on road surfaces, especially if this occurs close to junctions.

Trees planted close to junctions and points of access, if not correctly located, can also interrupt required clear sight lines (visibility splays), impeding visibility, and can be used as defence in the mitigation of road traffic accidents. All roadside trees, with a stem girth of 250 mm or more at maturity, are treated as hazards when planted within the verges of highways carrying fast-moving traffic. They are considered, for risk purposes, alongside other fixed objects, such as lamp columns, road signs and bridge abutments (The Highways Agency, 2006). Colliding at speed with a large tree can cause significant damage to both vehicle and driver and would either require removal, if within 9 m of the carriageway edge, or protection, with a vehicle-restraint system or barrier (The Highways Agency, 2006). For more formal and avenue planting along inter-urban road corridors and at approaches to settlements, large trees should be positioned at least 7.5 m from the edge of the carriageway (The Highways Agency, 2001a). It is interesting to read the range of responses to a Department for Transport funded Rural Road Safety Demonstration Project, where roadside trees have been planted along the approaches to four Norfolk villages, in an effort to reduce vehicle speed (Road Safety GB, 2010; Youde & Pang, 2010).

Problems are not restricted to road and rail transport; falling leaves and fruit can also create messy, slippery conditions on pedestrian routes. Footways and footpaths can be deflected by tree roots growing beneath them, creating uneven surfaces that can cause real concerns for people with mobility problems and the partially sighted. We live in an increasingly litigious society where local authorities are constantly under threat of personal injury law suits against trip and slip hazards. Large paving units used in close proximity to trees can create quite significant trip hazards, even if the root growth is fairly modest, simply due to the size of the paving unit (The Highways Agency, 2006).

Certain trees can release biogenic volatile organic compounds (BVOCs), allergenic pollen and other air-borne irritants, which can cause severe health problems to some susceptible people,

Figure 1.3
Fallen leaves and fruit can become a slip hazard in wet weather, especially in combination with steps or slopes. As with occurrences of snow and ice, management measures may need to be put in place to prevent slips, trips and falls.

especially problems of a respiratory nature, such as asthma. The BVOCs, mainly isoprene and monoterpenes, are produced during normally healthy growing conditions, but tend to increase when plants are subject to stress. Through a chain of atmospheric reactions, BVOCs are able to combine with nitrogen oxides (NO_x) from vehicle exhausts to create a variety of photochemical pollutants, including ozone (O_3). These pollutants and inhalable, air-borne particulate matter of less than 10 μm in diameter (PM_{10}) can cause inflammation of the respiratory tract to predisposed individuals. This size of 10 μm is important as only particles smaller than this are able to penetrate the respiratory tract deep into the alveoli of the lungs, where they can settle and cause irritation. Although pollen grains typically range from 15 to 40 μm, and so tend to be restricted to the upper respiratory tract, the allergens contained within them can be transferred to other air-borne pollutants within the PM_{10} range and less, allowing them to be inhaled deep into the lungs. For this reason, inhabitants of urban areas, subject to elevated levels of air-borne pollution, tend to show a higher incidence of pollen allergies than those resident in suburban and more rural areas (D'Amato, 2000; D'Amato *et al.*, 2007).

Although the actual incidence of crime in woodlands, parks and other green spaces is generally very low, they are often considered to be unsafe. Because of this common perception of being dangerous, such spaces often encourage feelings of anxiety and insecurity, especially among women, who respond by avoiding using them, especially if they are alone and it is dark (Burgess, 1995; Koskela & Pain, 2000; Jorgensen & Anthopoulou, 2007). There is also a perception among some immigrant and ethnic communities that wooded areas and green open spaces are intrinsically dangerous, either due to spaces being subject to low levels of surveillance or the presence of dogs (Rishbeth, 2001; Lyytimäki & Sipilä, 2009) and the concomitant dog excrement not collected by uncaring owners.

The consideration of ecosystem disservices, when assessing the effects of urban green infrastructure, is a fairly recently emerging one. The typical assumption is that urban trees and other green infrastructure benefit society by providing a range of ecosystem 'goods'. Perhaps, a more realistic scenario is that a multiple and wide-ranging set of ecosystem outputs are produced, which can be considered as either beneficial or deleterious. It is important to have regard for both the positive and the negative ecosystem outputs whenever assessments of the quality of life for urban-dwelling communities is being linked to, or measured against, ecosystem structure and function.

1.4.2 Subsidence claims

If the ground on which building foundations are situated moves or sinks, this movement often manifests itself by signs of diagonal cracking, typically wider at the top than at the bottom and especially during prolonged periods of dry weather. In susceptible soils, known as the *shrinkable clays*, the volume of the soil alters in relation to the amount of water it contains. As the water content rises (typically during the winter), the clay swells. As the water content decreases either through evaporation or transpiration by plants, the soil shrinks. This cyclic shrinking and swelling is often the cause of subsidence.

Trees and other vegetation extract water from the soil, causing it to shrink, and so, are often implicated as the cause of structural damage to property, especially on the shrinkable clay soils of London and the south-east. However, outside these areas, the risk is fairly low, and even within London, the London Assembly recorded that only 5 per cent of all the trees felled between 2002 and 2007 were due to subsidence claims (GLA, 2007). The Mayor's *London Tree and Woodland Framework* suggests that the perceived threat of subsidence is far greater than the actual risk and estimates that less than 1 per cent of the total tree population has been proven to actually cause damage to the property (GLA, 2005). That said, it has been estimated that some 60 per cent of the national housing stock is constructed in areas where shrinkable clay soil predominates (O'Callaghan & Kelly, 2005).

Where there is clear and substantial evidence that trees are involved in subsidence cases, however, local authorities often remove the trees concerned or grant permission for removal, rather than risk expensive repair costs being claimed later. Developers have been known to exploit this as has the media in search of a 'good' story.

The National House-Building Council (NHBC) provides guidance for suitable foundations close to trees. It states that 'Foundations shall be capable of accommodating the effects of trees and hedgerows on shrinkable soils without excessive movement' (NHBC, 2014).

Conventional landscape paradigms in our urban environment, and tree planting in particular, are being challenged as never before. As urban planning and landscape practitioners, we need to look beyond the aesthetic and think much more creatively. Our cities need to be multi-functional, they need to be able to adapt to the expected increases in population and the uncertain outcomes of predicted climate change. To help inform our design objectives, there is a wealth of research out there, which supports the benefits of trees.

1.5 THE BENEFITS

Great emphasis is placed on interpreting current scientific thinking around ecosystem services into regular language and assigning economic values to them, as a way to help inform politicians and other decision-makers on current versus future costs and benefits, when comparing ecological with technological approaches. For such purposes, ecosystems can be regarded as capital assets, yielding flows of vital services, such as the production of goods (provisioning services), life-support processes (regulating services) and conditions that make life worthwhile (cultural services). In this way, it should be possible to develop integrated ecological–economic–social approaches to managing ecosystem assets, and so, embody human welfare within local, regional and national environmental, development and climate change adaptation policies.

Some argue that the economic valuation of goods and services provided by ecosystems is not particularly wise and can certainly be risky (Ludwig, 2000). However, we are already making valuation judgements on ecosystems and ecosystem function. Choices are being made about ecological assets all the time, and each must be based on some form of value-based system, whether it is a monetised system or not (Costanza *et al.*, 1997).

The term 'natural capital' is often used to describe the natural ecosystem assets that provide the goods and services for people. The Natural Capital Committee (NCC), chaired by Professor Dieter Helm, was established in 2012 to independently advise the UK government 'on how to ensure England's "natural wealth" is managed efficiently and sustainably, thereby unlocking opportunities for sustained prosperity and well-being' (NCC, 2015). The NCC has provided a framework for developing a strategy and 25-year plan that considers sustainable economic growth alongside health and well-being and identifies potential actions and initiatives that could be taken to help deliver these services while enhancing the natural capital that facilitates them.

1.5.1 Social and health benefits

Frances Kuo and William Sullivan, from the University of Illinois at Urbana-Champaign, found that, contrary to popular belief and many academic studies, the presence of vegetation in urban areas may actually reduce the incidence of crime (Kuo & Sullivan, 2001). They suggest that the connection between trees and social ecosystem health is an extension of Oscar Newman's defensible space theory (Newman, 1972). The presence of trees can be a decisive factor in the extent to which residents take ownership of their local area, encouraging people out of their homes and into public open space, providing opportunities for informal social contact among neighbours. This helps to create a system of informal surveillance, which in turn can discourage potential perpetrators, while at the same time, mitigating some of the psychological precursors to violence.

Research conducted by Roger Ulrich of Texas A&M University showed that hospital patients who have a view of green space and trees recover faster and require less post-operative pain medication (Ulrich, 1984). Views of nature rapidly reduce the physiological stress response. Further studies by Ulrich and many others show that the heart rate, blood pressure and other body function measures return to normal levels more quickly when people view nature after a stressful experience (Ulrich, Simons, Losito, Fiorito, Miles & Zelson 1991). The Marmot Review of health inequalities recognises these benefits and places great emphasis on 'improving the availability of good quality open and green spaces across the social gradient' (Marmot *et al.*, 2010). Poor mental health costs the UK economy an estimated £26.1 billion per year (Faculty of Public Health, 2010). The Faculty of Public Health suggests that access to safe public green space may be as effective as prescription drugs in treating some mental health illnesses (Faculty of Public Health, 2010). There is increasing evidence to support the notion that people who live near trees benefit from living healthier and happier lives. In its report *Our Natural Health Service*, Natural England stated that 'If every household in England were provided with good access to quality green space it could save an estimated £2.1 billion in health care costs' (Natural England, 2009). When compared to the extraordinary sums of money involved with health provision, incorporating gardens in hospitals and other health care facilities and improving access to green space would appear to offer good value for money if such provisions can provide a range of health benefits for all social groups and reduce the overall cost of care.

1.5.2 Urban heat island effect

Today trees, as part of green infrastructure, are being recognised more and more as an important strategic asset. Ninety per cent of the UK residents live in an urban environment as does more than half the world population. Cities are hot, noisy places with poor air quality, prone to flash flooding during rain storms, and they consume vast quantities of energy to cool in summer and heat in winter. The heat island effect typically raises the mean city temperatures by approx 4°C above surrounding rural areas. This will be made worse by climate change. The urban heat island effect is mainly caused by energy from the sun being absorbed by buildings and hard surfaces where it is stored as heat. Most urban surfaces are dark (low albedo) and reflect often less than 10 per cent of this solar energy. This can be even lower in high-rise cities where the energy is reflected down into so-called urban canyons. At night, the stored heat is slowly released from the buildings and other hard infrastructure, keeping the air temperature high. Pollution, which tends to collect in urban canyons, can exacerbate the problem by helping to trap long-wave radiation and preventing it dissipating. Conversely, rural vegetation typically reflects approximately 25 per cent of the incoming radiation from the sun with much of the remainder being used to drive evapo-transpiration, an important component of the hydrologic cycle. Less energy, therefore, remains to heat the air by convection and the ground by conduction. This is nothing new. Trees have been used for centuries to reduce high summer temperatures by providing shade and by absorbing solar energy to evaporate water, and so, cool the air. Susannah Gill and the research team from the University of Manchester have calculated that increasing the tree cover of Manchester city centre by 10 per cent should reduce the maximum surface temperature by approximately 4°C, which they say should effectively ‘climate-proof’ the city up to, but not including, the UK Climate Impacts Programme (UKCIP) 2080s high-emissions scenario (Gill *et al.*, 2007).

1.5.3 Air quality

It can be shown that vegetation captures gases, aerosols and particulates more effectively than any other urban surface (Fowler *et al.*, 1989) and trees, because of the relatively large surface area of their canopies, are more effective still than ground or short vegetation (Fowler *et al.*, 2004; Powe & Wills, 2004). It should be noted that these studies looked principally at woodland rather than at individual trees. There are many other studies that have investigated the effects on urban air quality by urban street trees, for example, McPherson *et al.*, 1998; Nowak *et al.*, 2006; McDonald *et al.*, 2007; Selmi *et al.*, 2016 (in press).

The House of Commons Environmental Audit Committee, in its 2010 fifth report, acknowledged that premature deaths caused by air pollution in the UK were likely to be in the region of 35,000 for the year of 1998 (*Air Quality Fifth Report of Session 2009–10 Volume I Report, Together with Formal Minutes, 2010*). From the data gathered by the European Environment Agency (EEA), by 2012, the number had increased to over 52,000 (*Air Quality in Europe – 2015 Report, 2015*). The World Health Organization estimated that in 2012 ‘outdoor pollution was responsible for the deaths of some 3.7 million people under the age of 60’ worldwide (WHO, 2014). In addition, health impacts from air pollution are also expressed as an increase in morbidity (European Environment Agency, 2015).

The primary culprits for these adverse effects upon urban air quality are NO_X, O_3, sulphur dioxide (SO_2), air-borne particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}) and latterly, fine particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$).

Figure 1.4 Residential streets with little traffic movement are good locations for large canopy trees.

The larger particles, greater than 10 μm in diameter, tend to fall out of suspension, due to gravity, fairly quickly (a matter of a few hours). Conversely, those less than 10 μm are respirable, and so, small enough to enter the deepest parts of the human lungs, where they can settle and cause a variety of health problems. Urban particulates can contain toxic compounds of heavy metals, traffic exhaust emissions, car tyre materials and brake dust. Trees can intercept and slow air-borne particulate materials causing them to fix to leaves and branches. It has been claimed that a roadside sugar maple of 300-mm stem diameter can remove 60 mg cadmium, 140 mg chromium, 820 mg nickel and 5,200 mg lead from the air in one growing season (Coder, 2011). When it rains, these particulates can be washed onto the ground where they can be bound within the soil matrix. Trees have also been shown to absorb pollutant gases such as O_3, NO_x, SO_2, carbon monoxide and carbon dioxide (Hewitt, Stewart, Donovan & MacKenzie).

There have been many reports that cite the monetised outputs from computer models to provide evidence of effective ecosystem services improvement through the use of urban tree planting (Nowak, Greenfield, Hoehn & Lapoint, 2013). However, some caution needs to be taken when using such models as a lever to influence policy-making and to focus air improvement strategies towards the planting of urban trees. Air quality improvement is only one of the many benefits provided by urban tree planting, but it is a fairly modest gain. Nowak and co-authors modelled $PM_{2.5}$ removal by trees in ten US cities and calculated that air quality improvement, attributable to trees, may be between 0.05 per cent and 0.24 per cent. Calculating the benefits for New York City would provide an increased life expectancy of 0.64 years per capita. Only when this is multiplied by the overall population does a significant monetary value evolve. This, however, should not mask the fact that the effect realised by any single individual within the population is modest (Whitlow *et al.*, 2014).

In a study that looked at the estimated removal of particulate pollution (in this case PM_{10}) by urban trees in London, Tallis, Taylor, Sinnett, and Freer-Smith (2011) found that the resultant decrease in ambient pollution concentrations due to current tree cover to be somewhere in the region of 0.7–1.4 per cent. By increasing that existing tree cover by 50 per cent, the estimated removal of particulate pollution would increase to 1.1–2.6 per cent by the year 2050. They further postulate that specific targeting of tree planting, and especially street tree planting, to the most polluted areas would have the greatest benefit to future air quality. In other studies (Gromke & Ruck, 2007; Gromke & Ruck, 2009; Gromke, 2011; Gromke & Ruck, 2012; Pugh, MacKenzie, Whyatt & Hewitt, 2012; Wania *et al.*, 2012; Vos, Maiheu, Vankerkom & Janssen, 2013), it has been found that tree planting needs to be carefully considered in urban areas, especially if the pollution source is in a street canyon. Closely spaced tall buildings can create street canyons where wind speeds, at ground level, are low and air circulation is limited. If trees are planted within these canyons, airflow can be further obstructed and ventilation reduced, trapping pollutants beneath the tree canopy and causing a fumigation effect, thereby exposing pedestrians to increasing concentrations of street-level pollution. Where traffic is absent from the street canyon or infrequent, trees can provide valuable air filtering.

Vos, Maiheu, Vankerkom and Janssen (2013) suggest that the scale at which a study has been conducted will influence the conclusions that may be drawn, in terms of urban vegetation and urban air quality. When studying the local scale, it can be argued that street trees should be planted away from the pollution source to avoid reducing the ventilation, and so, causing a fumigation effect. For studies concerning an optimal city averaged air quality, Tallis, Taylor, Sinnett and Freer-Smith (2011) recommend that, as removal of pollutants increases with pollution concentration, tree planting should take place as close to the source as possible. These apparently opposing views (what Vos *et al.* refer to as a ‘green paradox’) are purely due to the different scales of assessment. While planting trees may help in some situations, tree planting alone is unlikely to improve urban air sufficiently when compared to other more direct interventions, such as a reduction in the overall pollution loading (Whitlow *et al.*, 2014). The effects that urban trees have on urban air quality are not currently well-enough understood to enable good mitigation strategies to be defined. More multi-scale approaches are required within a single study (Vos, Maiheu, Vankerkom & Janssen, 2013). With many urban local authorities struggling to meet their air quality standards, some may feel encouraged to invest their already stretched resources into planting trees to counter air quality problems, rather than to focus these resources directly towards strategies aimed at reducing emissions. Urban development has steadily replaced what was previously vegetated land with buildings roads and other hard infrastructure. Trees and other green infrastructure are vital elements within the urban ecosystem, ‘but the system has been pushed far beyond its biological capacity to compensate for human disturbances like air pollution’ (Whitlow *et al.*, 2014).

1.5.4 Opportunities for community orchards

Until fairly recently, almost every suburban garden had its own fruit trees, and orchards were once widespread throughout the country. Indeed, British apple varieties originate from almost every county in Britain, from Scotland to Cornwall. Brogdale Collections, in Faversham, Kent, is home to the National Fruit Collection and holds 2,200 varieties of apple, 550 varieties of pear, 285 varieties of cherry, 337 varieties of plum, nineteen of culinary quince, forty-two varieties of nut, 318 of currants and four of medlar (Brogdale Collections, 2016). In 2007, traditional orchards were added to the UK Biodiversity Action Plan as a declining, priority habitat. An ever-increasing demand on land for development and cheap, imported fruit from around the world have been partly responsible for the demise of the domestic fruit tree. Orchards in villages and on the edges of towns are particularly vulnerable as prime targets for development. The National Trust claims that over 90 per cent of traditional English orchards have been lost since the 1950s (Cider Apple Collection Saved, 2016).

Common Ground was founded in 1983 by Sue Clifford, Angela King and Roger Deakin, with the aim of encouraging communities to make long-lasting connections with their local environment, through art, education and community gatherings. They started work on creating and conserving local orchards in 1992 and first produced a *Community Orchards Handbook* in 2008. This manual, now in its second edition, written by Angela King and Sue Clifford, provides a lessons-learned history of the philosophy and practicalities of creating orchards for and by the local community (King & Clifford, 2011).

In 2009, Carina Millstone and Rowena Ganguli set up the London Orchard Project, which became the Urban Orchard Project, promoting fruit growing and helping local community groups to establish orchards on housing estates, parks, colleges and other public spaces. Although the charity initially started in London, it is now spreading its programme to Birmingham, Manchester and Glasgow. Their most ambitious project has probably been the restoration of the orchard at Bethlem Royal Hospital in Bromley, Kent. The orchard, which dates from the 1920s, was rescued from a sea of brambles and is used to support occupational therapy and cookery classes for people with mental health problems.

One of the main advantages with fruit trees is that they are generally fairly easy to grow and can be quite productive, once they have established, with very little in the way of maintenance. Watering is required during the first growing season, some pruning will be necessary and mulching will help. Food can be such a good vector for crossing social and cultural barriers, and some existing community orchards have been incredibly successful at encouraging community cohesion through celebratory events, horticultural education, fruit production, harvest, juicing and preserving.

1.5.5 Enhanced property prices

The links between property values or consumer behaviour and the proximity of green space and street trees have been talked about in American research literature for many years. By reviewing the actual sale prices of residential property against a range of other property attributes, using a hedonic pricing model, Morales (1980), Morales *et al.* (1983), Anderson and Cordell (1988) were able to analyse the effect that trees may have on property values. In Athens, Georgia, Anderson and Cordell (1988) estimated the average property value enhancement provided by medium to large front garden trees equated to 3.5–4.5 per cent. Morales (1980), found that in Manchester, Connecticut, 'good tree cover' could attribute between 6 and 9 per cent of the total sales price. More recent American research by Donovan and Butry (2010) looked at estimating the effects of street trees on sale prices of residential properties in Portland, Oregon. They found that the combined effects of number of trees fronting the property and overall crown area within 30.5 m of the house raised the sales price by an average of 3 per cent.

These studies used multiple regression analysis to calculate values between the many elements that contribute to the sales prices of property. This enables individual variations between properties to be factored into the statistical calculations to create a 'level playing field' when making comparisons. That said, the results from any study such as these must be treated with some caution if any definite claims are made. As Anderson and Cordell point out, the regression analysis will

Figure 1.5
The fresh green foliage of these Norway maples provides some welcome dappled shade in the summer and helps to keep the rain off shoppers.

not necessarily differentiate between a causal link and an association. The increase in sale price may not be solely due to the presence of trees, but may be due to other features that are *associated* with trees. An example provided by the authors is that properties with fireplaces were statistically more likely to have higher numbers of trees in their front gardens. In this example, it is difficult to categorically state what proportion of the sale price is attributed to either trees or to fireplaces alone. This is a known limitation of hedonic models and is known as collinearity.

In the UK, the GLA commissioned a report *Valuing Greenness: Green Spaces, House Prices and Londoners' Priorities* (GLA, 2003), which confirmed a link between proximity of urban green space and enhanced property prices in London. It found that within a typical London Ward, a 1 per cent increase in green space could lead to a 0.3–0.5 per cent increase in local property prices. Although the report does not mention trees specifically, its main focus was on urban parks and play areas, where trees invariably form a key element within the space. CABE (Commission for Architecture and the Built Environment) took this and other international studies to develop their own in-depth, case-study approach. Their report suggested property value premiums, for properties close to urban parks, of 3–34 per cent, with typical value lifts being in the region of 5–7 per cent (the highest value of 34 per cent, for Mowbray Park in Sunderland, is also thought to be due to other factors such as proximity to the city centre). As an example, the valuation of properties overlooking the restored Queen Square in Bristol was found to be 16 per cent higher than comparable properties elsewhere.

Another aspect of trees in close proximity to buildings, and which has an effect on values, is what attracts people to and how they behave in retail districts. Most of the available research in this area has been produced by Kathy Wolf of the University of Washington, Seattle, Washington. Initial survey results from shoppers suggested that trees are 'important components of a welcoming, appealing consumer environment' (Wolf, 2003). In addition, shoppers were prepared to travel further to visit retail areas with trees, visit more often, pay more for parking once there and spend longer shopping. The argument that car parking spaces lost to tree planting is an over-extravagant use of space appears not to be supported (Wolf, 2003). Results from a later case study, where visitors to the business district of Athens, Georgia, were interviewed, are consistent with the earlier survey. In addition, large, full canopy trees are preferred over smaller, less significant varieties. Interestingly, modern architecture, visually buffered by trees, was found to be preferable to historic buildings without trees (Wolf, 2004).

Shoppers' attitudes to the broader environment within which they are shopping should not come as any surprise. There is extensive retail and consumer behavioural science to inform retailers' marketing strategies which, in turn, guide marketing decisions such as product packaging, shop layout and décor, ambiance and consumer experience, among other things (e.g., Baker & Grewal, 1994; Donovan & Rossiter, 1994; Grewal & Baker, 1994).

1.5.6 Cultural heritage

Trees form a significant part of Britain's historic, cultural and ecological heritage, with these lands containing a high proportion of the ancient trees present in Northern Europe (Fay, 2002). It has even been claimed that there are more ancient trees in Windsor Great Park alone than in the whole of either France or Germany (Stokes & Rodger, 2004). Some ancient trees especially have been treasured by many generations and may be relics or remnants of ancient woods, so providing a direct, historical link back to a previous age and, as such, help to inform local identity and the particularities of a place. They have always held interest for painters, poets and other aesthetes, for their significant and unique contribution to the landscape. They may also contain an important gene pool and so have the potential to provide an enormous biological resource for modern plant breeding. Many were managed as sources for animal fodder, timber or firewood, with many of these pollards and coppices still visible today.

Veteran trees are not as old as ancient trees, but show some ancient tree characteristics, such as low, squat shape with a wide trunk and a canopy that has reduced in size, compared with other specimens. Sometimes, the trunk will show signs of hollowing but this may not be present or visible. Often the characteristic signs have been caused by weather damage, particular tree management techniques or by the environment in which the tree is growing. Many ancient trees are to be found in current and former parkland, such as Windsor Great Park and Greenwich Park, in south-east London. Some ancient and veterans will be present in old hedgerows as boundary trees.

Although it is unusual, sometimes ancient, but less infrequently veteran, trees are affected by development proposals. In these situations, careful consideration needs to be given to the tree, and specialist advice should be sought. One such advisory body is the Ancient Tree Forum, which was launched in 1993, with the aim of promoting the value and importance of ancient and veteran trees and providing guidance on their management, to secure conservation wherever possible.

Figure 1.6
Some of the magnificent sweet chestnuts (*Castanea sativa*) in Greenwich Park are over 400 years old, making them ancient trees. These are remnants of Charles II's formal French-style park, designed by Le Notre in the early 1660s.

1.5.7 Source of fuel

Over the last decade or so, wood has become an increasingly attractive source of low carbon energy in the UK along with other forms of biomass. Indeed, Policy 5.1 of the London Plan sets a carbon dioxide (CO_2) emissions reduction target of 60 per cent below 1990 levels by 2025. There is an expectation that all new development will contribute to this ambitious target through the application of Policy 5.2, which sets zero carbon targets for buildings within major developments of 2016 for residential buildings and 2019 for non-domestic buildings (GLA, 2016). Development proposals should demonstrate how they intend to use less energy, supply energy efficiently and use renewable energy to achieve these targets. The use of biomass is often seen as a cost-effective way to make a significant impact on CO_2 emissions reduction, either as a source of heating alone or by using combined heat and power (CHP) systems, to provide both heating and electricity.

The London Borough of Croydon and environmental consultants BioRegional established a working relationship in 1995 with the aim of improving tree and woodland management within the borough. In addition to some areas of woodland being returned to coppice management, the Croydon Tree Station was set up as part of the council's green waste recycling initiative. This facility was created to make better use of the arboricultural waste, generated by the council's

Figure 1.7
Pieter Bruegel the Elder: *The Gloomy Day (De sombere dag)*. One of the set of six paintings depicting different times of year. The 1565 scene clearly shows woodsmen collecting brushwood from pollarded trees, thought to be willow switches, in late winter or early spring (Mike Aling).

management of its 35,000 street trees, 400 hectares of woodland, parks and other trees in its ownership. The larger arisings from the management of this green infrastructure resource were redirected for selling as either firewood, raw materials for wood-turning and other crafts or made into charcoal. In 1999, LB Croydon was the first local authority in the world to achieve the Forest Stewardship Council (FSC) certification for the management of its street and park trees (BioRegional, 2006).

The Beddington Zero Energy Development (BedZED) was completed and occupied in 2002 and provided an opportunity for using the low-grade arboricultural arisings from the Croydon Tree Station, not suitable for other higher-value purposes. BedZED is reported as being both the first large-scale and the largest mixed-use, carbon neutral development in the UK. Peabody Trust led the project in partnership with the designer, Bill Dunster Architects, and BioRegional. An important part of its zero carbon strategy was the use of wood chip fuel for the CHP boiler and the 1,100–1,200 tonnes of wood chip required each year would be met by the Croydon Tree Station (BioRegional, 2006). City Suburban Tree Surgeons Limited were contracted to manage the council's trees and became interested in the Tree Station project, first becoming a partner and then later managing and operating the facility.

Currently, the majority of wood chip production at the Croydon Tree Station (now the Croydon Timber Station) is sent to the Slough CHP facility, the UK's largest dedicated biomass plant. With the potential to save the equivalent of 7 mega tonnes of CO_2 emissions each year, biomass as heating fuel is one of the most cost-effective and environmentally sustainable ways to decrease UK greenhouse gas emissions (Read, Freer-Smith, Morison, Hanley, West & Snowden, 2009).

1.5.8 Mitigation against flooding

Throughout history, we have settled low-lying areas, in close contact with rivers, estuaries and coastal enclaves. Europe has seen its fair share of major floods in recent years, and this is raising fears that extreme flood events are likely to be increasing due to climate change. The UK Meteorological Office predictions of a 33 per cent increase in winter precipitation along the western side of the UK, under the medium emissions scenario (Murphy *et al.*, 2009), have tended to focus the mind and helped to push the management of flood risk higher up the political agenda. To make matters worse, the built environment is constantly expanding, increasing the area of hard, impervious surfaces, and so, decreasing the area available for water infiltration. Increased water run-off increases erosion and sediment loading on existing surface water systems, which in turn can cause flooding. Sea-level rise and the predicted increase in rain storm intensity due to climate change will make this more problematic. Sea water is not necessarily restricted to the high-tide line along the shore; it can also be encountered inland, deep within the ground, finding its way below fresh water aquifers. As sea levels rise, this inland salt water can push the fresh water up towards the surface, raising the water table and reducing the soil's ability to absorb heavy and persistent rainfall (Gaines, 2016). If the sea level rises sufficiently in some low-lying coastal areas, the elevated fresh water could actually break the surface, as has already been experienced in Miami, Florida, during spring tides (McKie, 2014; Parker, 2015).

It is well known that trees and other vegetation can be shown to intercept, slow and absorb water in forests and woodland ecosytems (Crockford & Richardson, 2000). Researchers at Ghent University in Belgium found that a single beech tree in an oak–beech forest was found to intercept an average of 21 per cent of the precipitation over a 2-year period (Staelens, De Schrijver, Verheyen & Verhoest, 2008). As rainfall interception is mainly due to foliation, it is reasonable to assume that these results should be consistent with urban tree studies. Indeed, a rainfall interception study in Oakland, California, found that 25 per cent of the gross precipitation could be intercepted by deciduous urban trees (Xiao & McPherson, 2011). This is supported by other studies where similar interception rates for a Callery pear (*Pyrus calleryana*) and a cork oak (*Quercus suber*) in Davis, California, were found to average 15 per cent and 27 per cent, respectively (Xiao, McPherson, Ustin, Grismer & Simpson, 2000). Research at the University of Manchester estimates that increasing the tree cover within the residential areas of Greater Manchester by 10 per cent would reduce local surface water run-off by 5.7 per cent (Gill, Handley, Ennos & Pauleit, 2007).

Armson *et al.* found that tree planting pits within test plots surfaced with sealed asphalt were able to absorb significant amounts of surface water run-off (Armson *et al.*, 2013). Trees also direct rainwater to flow along branches and down stems (stemflow) to the base of the tree, where, ideally, it enters the ground. It has also been shown that the roots of some tree species are able to penetrate saturated, compacted subsoils and alter the drainage properties by increasing soil permeability (Bartens *et al.*, 2008). Highly permeable, engineered rooting media have been used for some time, where trees are grown in paved areas, due to their suitability to be compacted sufficiently to support paving systems, while at the same time, allowing root growth. These media are now finding favour with designers seeking opportunities to store surface water run-off. Although green infrastructure alone cannot be relied upon to moderate the expected volumes of surface water run-off under predicted climate change, it could prove useful, especially if integrated with other Sustainable Drainage System (SuDS) measures. For more information, see the CIRIA *SuDS Manual* (Woods Ballard *et al.*, 2015).

1.5.9 Carbon sequestration

Trees are massive carbon sinks, so they can help combat climate change and global warming. The Read Report estimated that a maximum carbon stock of approximately 790 mega tonnes of carbon (MtC) is stored in UK forests, including the soil in which they are growing. In addition, about 15 $MtCO_2$ (4 MtC) is removed from the atmosphere each year (Read, Freer-Smith, Morison, Hanley, West & Snowden, 2009). Clearly, most forestry plantations are located in rural areas;

Figure 1.8
Rain interception can be clearly seen by the lighter colour of the ground beneath the trees.

however, a 2011 UK study did consider the biological carbon storage within the city of Leicester and estimated that over 230 KtC is stored in above-ground vegetation. Of this, 97.3 per cent (225 KtC) consists of carbon stored in trees (Davies, Edmondson, Heinemeyer, Leake & Gaston, 2011). Due to lower tree density alone, urban forests are likely to store and sequester less carbon than commercial forests per unit area. However, when considering per unit tree cover, urban forests may outperform their commercial cousins. This is due to the higher proportion of larger trees in urban environments and faster growth rates due to more open growing conditions with less competition from other trees. In fact, individual urban trees may contain four times more carbon than individual trees growing in forest stands (Nowak & Crane, 2002).

1.5.10 Biodiversity and wildlife

The importance of enhancing the potential for biodiversity within urban wildlife is more than simply addressing the instinctive bond between humans and other living systems, as developed by E.O. Wilson in his concept of biophilia. Urban green infrastructure can provide important refuges and movement corridors for a variety of species, especially if they connect with open green space, parks or areas of woodland. Esteban Fernández-Juricic investigated the bird populations found in tree-lined streets in Madrid, with a range of different levels of connectivity, vegetation structure and human disturbance (both pedestrian and vehicular). He found that wooded streets contained several bird species and could function as movement corridors (Fernández-Juricic, 2000). Improving the quality of the connected urban parks through the introduction of some fairly low-level enhancements, such as nesting boxes and feeding stations, could be quite easy ways to increase urban bird diversity (Fernández-Juricic & Jokimäki, 2001). The city of Christchurch in New Zealand has been shown to be more floristically diverse than the surrounding pastoral landscape (Stewart, Ignatieva, Meurk & Earl, 2004). High biodiversity was also recorded in urban parks within Flanders, Belgium (Cornelis & Hermy, 2004), supporting the notion that large urban and suburban parks may be considered ‘biodiversity hotspots’, as concluded by Fernández-Juricic & Jokimäki (2001).

1.6 WELCOME TO THE ANTHROPOCENE AGE

In 2000, Paul Crutzen, from the Max-Planck-Institute for Chemistry, and Eugene Stoermer, of the University of Michigan, proposed that the current geological age be defined under the name 'Anthropocene' (Crutzen & Stoermer, 2000). They argued that this term more accurately reflects the state of change experienced during the post-glacial geological epoch of the past 12,000 years, known as the Holocene (translated as 'recent whole'), and describes the impacts that human activities are placing on the earth and its atmosphere, at all scales.

Prior to the Industrial Revolution of the late eighteenth century, humankind's impact on the earth tended to be fairly insignificant and predominantly local. A new fossil fuel-based system of energy provided the opportunity for the mechanised extraction, manufacture and processing of materials, which in turn created conditions suitable for the exponential growth of the world's population. Such growth, and the prosperity and health that have accompanied it, inevitably place an ever-increasing demand for more and more of the earth's resources, from mineral deposits to fertile land, water and fish stocks (Steffen *et al.*, 2004).

The Anthropocene is characterised by the earth's biosphere being pushed beyond its normal operating range and being subjected to forces that are greater than those exerted by natural cycles. The planet is under pressure from its inhabitants as never before, and all this comes with concomitant land cover transformation, biodiversity loss, pollution and climate change, whose implications are globally significant in magnitude.

There are very few geographical areas over which humans have not had some influence. Even if this is not a direct influence, the effects of climate change can be seen throughout the world. The climate change debate will continue to rumble on with some arguing that there is no doubting the correlation between the burning of fossil fuel, atmospheric CO_2 levels and global temperature rise; the other side arguing that atmospheric changes are due to natural, cyclic phenomena. There is little doubt that change is happening, whatever the cause, and the speed of this change is increasing exponentially, so we need to accept it and plan accordingly. Climate change is often, mistakenly, referred to as global warming. I have had many conversations with students and others who state quite clearly that they look forward to the mild winters, and more predictably, hotter summers, which the term implies. Unfortunately, climate change is unlikely to manifest itself in such ways. An increase in global temperature leads to an overall increase in energy within the atmospheric system, and this energy is more likely to cause disrupted and erratic weather events, rather than predictable and steady patterns. Periods of unseasonal or exceptionally warm weather could quickly be followed by unusually severe cold and intense storms. Therefore, not only does our wildlife need to be able to adapt to the steadily increasing rise in overall temperature, but also to an erratic and unpredictable set of weather conditions, such as heat-waves, droughts and flooding.

1.6.1 Phenology

The influence of climatic change on biological systems is fairly easy to see from phenological records that date back to the early eighteenth century. Phenology is the study, through observation and record, of particular natural, seasonal events. For instance, an observer may record the date when they hear the first cuckoo call or when a particular oak tree comes into leaf or a particular hawthorn produces its first blossom. By recording these details over a period of time and making comparisons with previous datasets, changes may be observed.

Robert Marsham is considered to be the founding father of phenology, in Britain, recording his 'Indications of Spring' between 1736 and his death in 1798. Gilbert White was making similar phenological observations in Selborne, Hampshire, which were later supplemented with William

Markwick's own records for Catsfield, near Battle, Sussex, and published collectively in *The Natural History and Antiquities of Selborne*, in 1789 (White, 1789). Marsham's records were added to by successive generations of the family, finally ending with the death of Mary Marsham, in 1958. In addition to the annual variations in seasonal occurrences, these data have allowed the investigation of long-term trends and show an observable, gradual increase in temperature. These trends have been confirmed by later datasets, mainly from amateurs around the country. Since 1947, Jean Combes has been recording the dates when the first oak, ash, horse chestnut and lime leaves appear. These data have been invaluable to phenologists and those interested in tracking climate change, as they cover the post-war period when climate change was beginning to be considered as a major environmental challenge. In the autumn of 2000, the Woodland Trust and the Centre for Ecology and Hydrology came together with the view to provide a repository and research facility, promoting phenology around the country. Some 50,000 phenologists, many of them amateurs, continue to provide their data through the Nature's Calendar survey.

Using phenology data from the Nature's Calendar survey and other UK sources, a team of researchers, led by Tatsuya Amano of the National Institute for Agro-Environmental Sciences in Japan, analysed almost 400,000 'first flowering' records from 405 UK plant species. The records, which date back to 1760, indicate that over the last 25 years, flowers have been blooming between 2.2 and 12.7 days earlier than in any other consecutive 25-year period since 1760. They also show that this advance in 'first flower' date correlates with a mean temperature increase during February to April, with each 1°C rise in the mean temperature advancing flowering by an average of 5 days (Amano *et al.*, 2010).

REFERENCES

Amano, T., Smithers, R. J., Sparks, T. H. & Sutherland, W. J. (2010). A 250-year index of first flowering dates and its response to temperature changes. *Proceedings of the Royal Society B*, 22nd August, *277*(1693), 2451-7. Available at: http://rspb.royalsocietypublishing.org/content/277/1693/2451.full.pdf.

Anderson, L. M. & Cordell, H. K. (1988). Influence of trees on residential property values in Athens, Georgia (USA): A survey based on actual sales prices. *Landscape and Urban Planning, 15*(1–2), 153–64. doi:10.1016/0169-2046(88)90023-0

Armson, D., Stringer, P. & Ennos, A. R. (2013). The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. *Urban Forestry & Urban Greening, 12*(3), 282–6.

Baker, J. & Grewal, D. (1994). The influence of store environment on quality inferences and store image. *Journal of the Academy of Marketing Science, 22*(4), 328–39. doi:10.1177/0092070394224002

Barkham, P. (2009). *Thousands of urban trees mauled and destroyed as 'weapon dog' owners train animals for fighting.* Retrieved 23 November 2014 from *The Guardian*, News, World News, Animals: www.theguardian.com/world/2009/aug/11/urban-trees-destroyed-fighting-dogs.

Bartens, J., Day, S., Harris, J. R., Dove, J. & Wynn, T. (2008). Can Urban Tree Roots Improve Infiltration through Compacted Subsoils for Stormwater Management?. *Journal of Environmental Quality*, November, *37*(6), 2048–57.

Benedict, M. A. & McMahon, E. T. (2006). *Green Infrastructure: Linking Landscapes and Communities.* Washington, DC: Island Press.

BioRegional (2006). *Wood Chip Production from Tree Surgery Arisings in Croydon.* London: BioRegional Development Group. Retrieved from www.bioregional.com/wp-content/uploads/2015/05/WoodChipProduction_Apr06.pdf.

Britt, C. & Johnston, M. (2008). *Trees in Towns II – A New Survey of Urban Trees in England and their Condition and Management*. London: Department of Communities and Local Government.

Brogdale Collections (2016). *Brogdale Collections: The Home of the National Fruit Collection*. Retrieved 30 July 2016 from www.brogdalecollections.org/the-fruit-collection/.

Burgess, J. (1995). *Growing in Confidence: Understanding People's Perceptions of Urban Fringe Woodlands*. Cheltenham: Countryside Commission.

Coder, K. D. (2011). *WSFNR1101 Identified Benefits of Community Trees & Forests CF.* Retrieved 22 May 2015 from www.warnell.uga.edu/outreach/pubs/pdf/forestry/Community%20Tree%20Benefits%2011-01.pdf.

Cornelis, J. & Hermy, M. (2004). Biodiversity relationships in urban and suburban parks in Flanders. *Landscape and Urban Planning, 69*(4), 385–401. doi:10.1016/j.landurbplan.2003.10.038

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M,. Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387(6630), 253-60. doi: 10. 1038/387253a0

Craul, P. J. (1985). A description of urban soils and their desired characteristics. *Journal of Arboriculture, 11*(11), 330–9. Retrieved from http://joa.isa-arbor.com/request.asp?JournalID=1&ArticleID=2052&Type=2.

Crockford, R. H. & Richardson, D. P. (2000). Partitioning of rainfall into throughfall, stemflow and interception: Effect of forest type, ground cover and climate. *Hydrological Processes, 14*(16–17), 2903–20. doi:10.1002/1099-1085(200011/12)14:16/17<2903::AID-HYP126>3.0.CO;2-6

Crutzen, P. J. & Stoermer, E. F. (2000). The 'Anthropocene' (W. Steffen, ed.) *Global Change News Letter No. 41* 17–18. Retrieved from www.igbp.net/download/18.316f18321323470177580001401/1376383088452/NL41.pdf.

D'Amato, G. (2000). Urban air pollution and plant-derived respiratory allergy. *Clinical and Experimental Allergy, 30*(5), 628–36. doi:10.1046/j.1365-2222.2000.00798.x

D'Amato, G., Cecchi, L., Bonini, S., Nunes, C., Annesi-Maesano, I., Behrendt, H., Liccardi, G., Popov, T. & Van Cauwenberge, P. (2007). Allergic pollen and pollen allergy in Europe. *Allergy: European Journal of Allergy and Clinical Immunology*, *62*(9), 976-90. doi: 10.1111/j.1398-9995.2007.01440.x

Davies, Z. G., Edmondson, J. L., Heinemeyer, A., Leake, J. R. & Gaston, K. J. (2011). Mapping an urban ecosystem service: Quantifying above-ground carbon storage at a city-wide scale. *Journal of Applied Ecology, 48*(5), 1125–34. doi:10.1111/j.1365-2664.2011.02021.x

Denham, C. & White, I. (1998). Differences in urban and rural Britain. In J. Fox (ed.), *Population Trends 91, Spring 1998*, 23–34. Retrieved from http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/rel/population-trends-rd/population-trends/no--91--spring-1998/difference-in-urban-and-rural-britain.pdf.

Doll, D., Ching, J. K. & Kaneshiro, J. (1985). Parameterization of subsurface heating for soil and concrete using net radiation data. *Boundary-Layer Meteorology, 32*(4), 351–72.

Donovan, G. H. & Butry, D. T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning, 94*, 77–83. doi:10.1016/j.landurbplan.2009.07.019

Donovan, R. J. & Rossiter, J. R. (1994). Store atmosphere and purchasing behavior. *Journal of Retailing, 70*(3), 283–94. doi:10.1016/0022-4359(94)90037-X

European Environment Agency. (2006). *Urban Sprawl in Europe: The Ignored Challenge. EEA Report 10/2006*. Copenhagen: European Environment Agency. Retrieved from www.eea.europa.eu/publications/eea_report_2006_10/eea_report_10_2006.pdf.

European Environment Agency. (2015). *Air Quality in Europe – 2015 Report.* Luxembourg: Publications Office of the European Union. Retrieved from www.eea.europa.eu/publications/air-quality-in-europe-2015/at_download/file.

Faculty of Public Health. (2010). *The Great Outdoors: How our Natural Health Service Uses Green Space to Improve Wellbeing*. London: Faculty of Public Health.

Fay, N. (2002). Environmental arboriculture, tree ecology and veteran tree management. *Journal of Arboriculture, 26*(3), 213–38. doi:10.1080/03071375.2002.9747336

Fernández-Juricic, E. (2000). Avifaunal use of wooded streets in an urban landscape. *Conservation Biology, 14*(2), 513–21. doi:10.1046/j.1523-1739.2000.98600.x

Fernández-Juricic, E. & Jokimäki, J. (2001). A habitat island approach to conserving birds in urban landscapes: Case studies from southern and northern Europe. *Biodiversity & Conservation, 10*(12), 2023–43. doi:10.1023/A:1013133308987

Firehook, K. (2015). *Strategic Green Infrastructure Planning: A Multi-Scale Approach.* Washington, DC: Island Press.

Florida Greenways Commission (1994). *Creating a Statewide Greenways System – For People . . . for Wildlife . . . for Florida.* Tallahassee, FL: Florida Greenways Commission.

Fowler, D., Cape, J., Unsworth, M., Mayer, H., Crowther, J., Jarvis, P., Gardiner, B. & Shuttleworth, W. (1989). Deposition of atmospheric pollutants on forests [and discussion]. *Philosphical Transactions of the Royal Society. Series B, Biological Sciences, 324*(1223), 247-65. Available at: http://rstb.royalsocietypublishing.org/content/324/1223/247.full.pdf.

Fowler, D., Skiba, U., Nemitz, E., Choubedar, F., Branford, D., Donovan, R. & Rowland, P. (2004). Measuring aerosol and heavy metal deposition on urban woodland and grass using inventories of ^{210}Pb and metal concentrations in soil. *Water, Air, and Soil Pollution: Focus, 4*(2), 483-99.

Gaines, J. M. (2016). Flooding: Water potential. *Nature, 531*, S54–S55. doi:10.1038/531S54a

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), 115–33. doi:http://dx.doi.org/10.2148/benv.33.1.115

GLA (2003). *Valuing Greenness: Green Spaces, House Prices and Londoners' Priorities.* London: Greater London Authority. Retrieved 19 August 2011 from www.london.gov.uk/sites/default/files/valuing_greenness_report.pdf.

GLA (2005). *Connecting Londoners with Trees and Woodlands: A Tree and Woodland Framework for London*. London: Greater London Authority.

GLA (2007). *Chainsaw Massacre: A Review of London's Street Trees*. London: Greater London Authority.

GLA (2016). *The London Plan – The Spatial Development Strategy for London Consolidated with Alterations since 2011.* London: Greater London Authority. Retrieved 15 July 2016 from www.london.gov.uk/sites/default/files/the_london_plan_malp_final_for_web_0606_0.pdf.

Grewal, D. & Baker, J. (1994). Do retail store environmental factors affect consumers' price acceptability? An empirical examination. *International Journal of Research in Marketing, 11*(2), 107–15. doi:10.1016/0167-8116(94)90022-1

Gromke, C. (2011). A vegetation modeling concept for building and environmental aerodynamics wind tunnel tests and its application in pollutant dispersion studies. *Environmental Pollution, 159*(8–9), 2094–9.

Gromke, C. & Ruck, B. (2007). Influence of trees on the dispersion of pollutants in an urban street canyon – Experimental investigation of the flow and concentration field. *Atmospheric Environment, 41*(16), 3287–514.

Gromke, C. & Ruck, B. (2009). On the impact of trees on dispersion processes of traffic emissions in street canyons. *Boundary-Layer Meteorology, 131*(1), 19–34.

Gromke, C. & Ruck, B. (2012). Pollutant concentrations in street canyons of different aspect ratio with avenues of trees for various wind directions. *Boundary-Layer Meteorology, 144*(1), 41–64.

Helms, J. A. (1998). *The Dictionary of Forestry*. Bethesda, Maryland: Society of American Foresters. Available at: http://www.dictionaryofforestry.org/.

Hewitt, N., Stewart, H., Donovan, R. & MacKenzie, R. (n.d.). *Trees and Sustainable Urban Air Quality, Research Summary from Lancaster University.* Retrieved 26 August 2011 from www.es.lancs.ac.uk/people/cnh/docs/UrbanTrees.htm.

Hoff, H. (2001). Climate change and water availability. In J. L. Lozän, H. Graßl & P. Hupter (eds), *Climate of the 21st Century: Changes and Risks* (pp. 315–21). Hamburg: Wissenschaftliche Auswertungen.

House of Commons Environmental Audit Committee. (2010). *Air Quality Fifth Report of Session 2009–10 Volume I Report, Together with Formal Minutes.* London: The Stationery Office.

Jack-Scott, E., Piana, M., Troxel, B., Murphy-Dunning, C. & Ashton, M. S. (2013). Stewardship success: How community group dynamics affect urban street tree survival and growth. *Arboriculture & Urban Forestry, 39*(4), 189–96.

Jorgensen, A. & Anthopoulou, A. (2007). Enjoyment and fear in urban woodlands – Does age make a difference? *Urban Forestry & Urban Greening, 6*(4), 267–78. doi:10.1016/j.ufug.2007.05.004

King, A. & Clifford, S. (2011). *Community Orchards Handbook* (2nd edn). Cambridge: Green Books.

Koskela, H. & Pain, R. (2000). Revisiting fear and place: Women's fear of attack and the built environment. *Geoforum, 31*(2), 269–80. doi:10.1016/S0016-7185(99)00033-0

Kuo, F. E. & Sullivan, W. C. (2001). Environment and crime in the inner city: Does vegetation reduce crime? *Environment and Behavior, 33*(3), 343–67.

Lawrence, H. W. (2006). *City Trees: A Historical Geography from the Renaissance through the Nineteenth Century*. Charlottesville, VA: University of Virginia Press.

Lichter, J. M. & Lindsey, P. A. (1994). Soil compaction and site construction: Assessment and case studies. In G. W. Watson and D. Neely (eds.), *The Landscape Below Ground. Proceedings of International Workshop on Tree Root Development in Urban Soils* (pp. 126–30). Champaign, IL: International Society of Arboriculture.

Lindsey, P. & Bassuk, N. L. (1992). Redesigning the urban forest from the ground below: A new approach to specifying adequate soil volumes for street trees. *Arboricultural Journal, 16*(1), 25–39. doi:10.1080/03071375.1992.9746896

LTOA (2010). *Bark Better than Bite – Damage to Trees by Dogs. Best Practice Note.* London: London Tree Officers' Association. Retrieved from www.ltoa.org.uk/component/docman/cat_view/103-dog-damage-to-trees.

Ludwig, D. (2000). Limitations of economic valuation of ecosystems. *Ecosystems, 3*(1), 31–5. doi:10.1007/s100210000007

Lyytimäki, J. & Sipilä, M. (2009). Hopping on one leg – The challenge of ecosystem disservices for urban green management. *Urban Forestry and Urban Greening, 8*, 309–15.

Marmot, M., Allen, J., Goldblatt, P., Boyce, T., McNeish, D., Grady, M. & Geddes, I. (2010). *Fair Society, Healthy Lives: The Marmot Review – Strategic Review of Health Inequalities in England post 2010.* London: The Marmot Review. Retrieved from www.instituteofhealthequity.org/projects/fair-society-healthy-lives-the-marmot-review/fair-society-healthy-lives-full-report.

McDonald, A., Bealey, W., Fowler, D., Dragosits, U., Skiba, U., Smith, R., Donovan, R., Brett, H., Hewitt, C. & Nemitz, E. (2007). Quantifying the effect of urban tree planting on concentrations and depositions of PM_{10} in two UK conurbations. *Atmospheric Environment, 41*(38), 8455-67.

McKie, R. (2014). *Miami, the great world city, is drowning while the powers that be look away.* (Guardian News and Media) Retrieved 5 April 2016 from *The Guardian*: www.theguardian.com/world/2014/jul/11/miami-drowning-climate-change-deniers-sea-levels-rising.

McPherson, E. G., Klaus, I. S. & Simpson, J. R. (1998). Estimating cost effectiveness of residential yard trees for improving air quality in Sacramento, California, using existing models. *Atmospheric Environment, 32*(1), 75–84.

Millennium Ecosystem Assessment (2003). *Ecosystems and Human Well-Being: A Framework for Assessment.* Washington, DC: Island Press. Retrieved from www.unep.org/maweb/en/Framework.aspx#download.

Millennium Ecosystem Assessment (2005). *Overview of the Millennium Ecosystem Assessment*. Retrieved 31 March 2016 from Millennium Ecosystem Assessment: www.unep.org/maweb/en/About.aspx.

Montague, T. & Kjelgren, R. (2004). Energy balance of six common landscape surfaces and the influence of surface properties on gas exchange of four containerized tree species. *Scientia Horticulturae*, *100*(1–4), 229–49.

Morales, D. J. (1980). The contribution of trees to residential property value. *Journal of Arboriculture, 6*(11), 305–8. Retrieved from http://joa.isa-arbor.com/request.asp?JournalID=1&ArticleID=1694&Type=2.

Morales, D. J., Micha, F. R. & Weber, R. L. (1983). Two methods of valuating trees on residential sites. *Journal of Arboriculture, 9*(1), 21–4. Retrieved from http://joa.isa-arbor.com/request.asp?JournalID=1&ArticleID=1854&Type=2.

Murphy, J., Sexton, D., Jenkins, G., Boorman, P., Booth, B., Brown, K., Clark, R., Collins, M., Harris, G. & Kendon, L. (2009). *UK Climate Projections science report: Climate change projections*. Exeter: Met Office Hadley Centre. Available at: http://ukclimateprojections.defra.gov.uk/media.jsp?mediaid=87851&filetype=pdf.

National Trust (15 April 2016). *Cider Apple Collection Saved*. Retrieved 31 July 2016 from National Trust: www.nationaltrust.org.uk/news/cider-apple-collection-saved.

National Urban Forestry Unit (1999). *Trees and Woods in Towns & Cities: How to develop local strategies for urban forestry - A Guide*, Wolverhampton: National Urban Forestry Unit.

Natural England (2009). *Our Natural Health Service - The role of the natural environment in maintaining healthy lives*, York: Natural England. Available at http://webarchive.nationalarchives.gov.uk/20170205000001/http://publications.naturalengland.org.uk/file/65031.

NCC (2015). *The State of Natural Capital – Protecting and Improving Natural Capital for Prosperity and Wellbeing, Third Report to the Economic Affairs Committee*. London: Defra. Retrieved from www.gov.uk/government/publications/natural-capital-committees-third-state-of-natural-capital-report.

Network Rail (n.d.). *Network Rail, Community Relations, Trees and Plants*. Retrieved 28 March 2016 from Network Rail: www.networkrail.co.uk/community-relations/trees-and-plants/.

Newman, O. (1972). *Defensible Space: Crime Prevention Through Urban Design*. New York: Macmillan.

NHBC (2014). *NHBC Standards: Part 4 – Foundations.* Milton Keynes, Bucks: National House Building Council.

Nowak, D. J. & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution, 116*(3), 381–9. doi:10.1016/S0269-7491(01)00214-7

Nowak, D. J., Crane, D. E. & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening, 4*(3–4), 115–23.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E. & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution, 178*, 229–36.

O'Callaghan, D. P. & Kelly, O. (2005). Tree-related subsidence: Pruning is not the answer. *Journal of Building Appraisal, 1*(2), 113–29. doi:10.1057/palgrave.jba.2940011

Parker, L. (2015, February). *Climate Change Economics – Treading Water* (National Geographic Partners LLC). Retrieved 5 April 2016 from National Geographic: http://ngm.nationalgeographic.com/2015/02/climate-change-economics/parker-text.

Powe, N. A. & Willis, K. G. (2004). Mortality and morbidity benefits of air pollution (SO_2 and PM_{10}) absorption attributable to woodland in Britain. *Journal of Environmental Management, 70*(2), 119–28.

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 and Technology, 46*(14), 7692–9. doi:10.1021/es300826w

Randrup, T. B. (1998). Soil compaction on construction sites. In D. Neely & G. W. Watson (eds), *The Landscape Below Ground II. Proceedings of an International Workshop on Tree Root Development in Urban Soils* (pp. 146–53). Champaign, IL: International Society of Arboriculture.

Read, D. J., Freer-Smith, P. H., Morison, J. I., Hanley, N., West, C. C. & Snowden, P. (2009). *Combating Climate Change – A Role for UK Forests. An Assessment of the Potential of the UK's Trees and Woodlands to Mitigate and Adapt to Climate Change*. Edinburgh: The Stationery Office. Retrieved from www.tsoshop.co.uk/gempdf/Climate_Change_Main_Report.pdf.

Rishbeth, C. (2001). Ethnic minority groups and the design of public open space: An inclusive landscape? *Landscape Research, 26*(4), 351–66. doi:10.1080/01426390120090148

Road Safety GB (2010). *Road Safety News: Tree planting scheme sparks debate*. Retrieved 30 March 2016 from Road Safety GB: www.roadsafetygb.org.uk/news/1144.html.

Roman, L. A., Battles, J. J. & McBride, J. R. (2014). The balance of planting and mortality in a street tree population. *Urban Ecosystems, 17*(2), 387–404.

RSPCA (2011). *The Welfare State: Five Years Measuring Animal Welfare in the UK 2005–2009.* Horsham, West Sussex: Royal Society for the the Prevention of Cruelty to Animals.

Schroeder, H., Flannigan, J. & Coles, R. (2006). Residents' attitudes toward street trees in the UK and US communities. *Arboriculture & Urban Forestry, 32*(5), 236–46. Retrieved from http://joa.isa-arbor.com/request.asp?JournalID=1&ArticleID=2961&Type=2.

Selmi, W., Weber, C., Rivière, E., Blond, N., Mehdi, L. & Nowak, D. (2016). Air pollution removal by trees in public green spaces in Strasbourg city, France. *Urban Forestry & Urban Greening*, 17, 192–201.

Sjöman, H., Hirons, A. D. & Bassuk, N. L. (2015). Urban forest resilience through tree selection – Variation in drought tolerance in Acer. *Urban Forestry & Urban Greening, 14*(4), 858–65. doi:10.1016/j.ufug.2015.08.004

Spirn, A. W. (1995). Constructing Nature: The Legacy of Frederick Law Olmstead. In W. Cronon (ed.), *Uncommon Ground: Rethinking the Human Place in Nature*. New York: W.W. Norton & Company, Inc, 91–113.

Staelens, J., De Schrijver, A., Verheyen, K. & Verhoest, N. E. (2008). Rainfall partitioning into throughfall, stemflow, and interception within a single beech (*Fagus sylvatica* L.) canopy: Influence of foliation, rain event characteristics, and meteorology. *Hydrology Processes, 22*(1), 33–45. doi:10.1002/hyp.6610

Steffen, W., Sanderson, A., Tyson, P., Jäger, J., Matson, P., Moore III, B., Oldfield, F., Richardson, K., Schellnhuber, J., Turner II, B. & Wasson, R. (2004). *Global Change and the Earth System: A Planet under Pressure*. (First ed.). Berlin Heidelberg: Springer-Verlag. Available at: www.activeremedy.org/wp-content/uploads/2015/10/Global_Change_and_the_Earth_System_A_Planet_Under_Pressure-2004.pdf.

Stewart, G. H., Ignatieva, M. E., Meurk, C. D. & Earl, R. D. (2004). The re-emergence of indigenous forest in an urban environment, Christchurch, New Zealand. *Urban Forestry & Urban Greening, 2*(3), 149–58. doi:10.1078/1618-8667-00031

Stokes, J. & Rodger, D. (2004). *The Heritage Trees of Britain and Northern Ireland.* London: Constable and Robinson.

Tallis, M., Taylor, G., Sinnett, D. & Freer-Smith, P. (2011). Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning, 103*, 129–38.

The Highways Agency (2001a). *DMRB: Volume 10 Environmental Design and Management, Section 0 Environmental Objectives, Part 2, HA 56/92 New Roads, Planting Vegetation and Soils*. Retrieved 31 March 2016 from *Standards for Highways: Design Manual for Roads and Bridges*: www.standardsforhighways.co.uk/dmrb/vol10/section1/ha5692.pdf.

The Highways Agency (2001b). *DMRB: Volume 7 Pavement Design and Mainenance, Section 4 Pavement Maintenance Methods, Part 3, HD 40/01 Footway Maintenance.* Retrieved 31 March 2016 from *Standards for Highways: Design Manual for Roads and Bridges*: www.standardsforhighways.co.uk/dmrb/vol7/section4/hd4001.pdf.

The Highways Agency (2006). *DMRB: Volume 2 Highway Structures, Section 2 Special Structures, TD19/06 Requirement for Road Restraint Systems.* Retrieved 31 March 2016 from *Standards for Highways – Design Manual for Roads and Bridges*: www.standardsforhighways.co.uk/dmrb/vol2/section2/td1906.pdf.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science, 224*(4647), 420–1.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A. & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmenatal Psychology, 11*, 201–30.

UN Department of Economic and Social Affairs, Population Division (2008). *United Nations Expert Group Meeting on Population Distribution, Urbanization, Internal Migration and Development.* New York: United Nations.

UN Department of Economic and Social Affairs, Population Division (2014). *The World Population Situation in 2014.* New York: United Nations.

URBED (2004). *Biodiversity by Design - a guide for sustainable communities*, Manchester: Town and Country Planning Association. Available at : http://www.tcpa.org.uk/data/files/bd_biodiversity.pdf.

Vos, P. E., Maiheu, B., Vankerkom, J. & Janssen, S. (2013). Improving local air quality in cities: To tree or not to tree? *Environmental Pollution, 183*, 113–22.

Wania, A., Bruse, M., Blond, N. & Weber, C. (2012). Analysing the influence of different street vegetation on traffic-induced particle dispersion using microscale simulations. *Journal of Environmental Management, 94*(1), 91–101.

White, G. (1789). *The Natural History and Antiquities of Selborne*. London: B. White and Son. Available at: https://archive.org/download/naturalhistorya04whitgoog/naturalhistorya04whitgoog.pdf.

Whitlow, T. H. & Bassuk, N. L. (1988). Environmental stress in street trees. *Arboricultural Journal, 12*(2), 195–201.

Whitlow, T. H., Bassuk, N. L. & Reichert, D. L. (1992). A 3-year study of water relations of urban street trees. *Journal of Applied Ecology, 29*, 436–50.

Whitlow, T., Pataki, D., Alberti, M., Pincetl, S., Setala, H., Cadenasso, M., Felson, A. & McComas, K. (2014). Comments on Modeled $PM_{2.5}$ removal by trees in ten U.S. cities and associated health effects by Nowak et al. (2013). *Environmental Pollution*, August, *191*, 256.

WHO (2014). *Air Quality Deteriorating in Many of the World's Cities*. Retrieved from World Health Organization: www.who.int/mediacentre/news/releases/2014/air-quality/en/.

Wolf, K. L. (2003). Public response to the urban forest in inner-city business districts. *Journal of Arboriculture, 29*(3), 117–26. Retrieved from http://joa.isa-arbor.com/request.asp?JournalID=1&ArticleID=85&Type=2.

Wolf, K. L. (2004). Trees and business district preferences: A case study of Athens, Georgia, US. *Journal of Arboriculture, 30*(6), 336–46. Retrieved from http://joa.isa-arbor.com/request.asp?JournalID=1&ArticleID=163&Type=2.

Woods Ballard, B., Wilson, S., Udale-Clarke, H., Illman, S., Scott, T., Ashley, R. & Kellagher, R. (2015). *The SuDS Manual.* London: CIRIA. Retrieved from https://ciria.sharefile.com/d-scf5d73d72bf4fc2b.

Xiao, Q. & McPherson, E. G. (2011). Rainfall interception of three trees in Oakland, California. *Urban Ecosystems, 14*(4), 755–69. doi:10.1007/s11252-011-0192-5

Xiao, Q., McPherson, E. G., Ustin, S. L., Grismer, M. E. & Simpson, J. R. (2000). Winter rainfall interception by two mature open-grown trees in Davis, California. *Hydrological Processes, 14*(4), 763–84. doi:10.1002/(SICI)1099-1085(200003)14:4<763::AID-HYP971>3.0.CO;2-7.

Youde, K. & Pang, S. (2010). *Tree Scheme Slows Down Fast Drivers*. Retrieved 30 March 2016 from *Independent*: www.independent.co.uk/life-style/motoring/motoring-news/tree-scheme-slows-down-fast-drivers-2053057.html.