Arboricultural Journal 1996, Vol. 20, pp. 161–172

Printed in Great Britain

VEGETATION AND SUSTAINABLE CITIES†

*M. Lawson**

Summary

The value of trees in urban areas has long been established. Trees offer significant opportunities as buffers of pollution on the pollution pathway. Pruning strategies of local authorities will affect the ability of trees to act as a target for pollutants. Within the United Kingdom current trends for overpruning to control water use ignore the potential for trees to be an integral part of urban pollution control. The impact of cyclical pruning policies upon human health, plant/animal communities and structures could be significant.

'Fog everywhere. Fog up the river, where it flows among green aits and meadows, fog down the river, where it rolls defiled among the tiers of shipping and the waterside pollutions of the great (and dirty) city. Fog on the Essex marshes, fog on the Kentish heights. Fog lying out on the yards and hovering on the rigs of great ships. Fog in the eyes and throats of ancient Greenwich pensioners, wheezing by the firesides.' **Bleak House. Charles Dickens**

Introduction

In the United Kingdom trees have been recognised as conveying significant amenity and landscape benefits to the general public since the 1930s/1940s. At that time Parliament included within the Town and Country Planning Acts detailed provisions for the protection of trees by special Tree Preservation Orders. (ANONa, 1947). These orders were effective for trees in areas, woodlands, groups and as individuals as long as the trees were visible from some public vantage point and were considered as having an amenity value. The Highways Act, 1980 (ANONb, 1980) gave further parliamentary power to local authorities to plant and maintain trees along the public highway.

In the United States, during the early 1950s it was recognised that trees could have a beneficial impact on pollution control and energy efficiency savings. (DEERING, 1956). By the 1970s there was a wealth of published data that confirmed the value of trees as sinks and buffers for airborne pollutants.

*O'Callaghan and Associates, Valleyfield, 1a, Stratford Road, Liverpool L19 3RE.
†Presented at the Quarterly Meeting of the London Tree Officers Association, July, 1995.

(MURPHY *et al*, 1977, SMITH and DOCHINGER, 1976 and SMITH and STASKAWICZ, 1977). An unofficial United Nations report in 1972, citing figures from the United States Council for Environmental Quality, claimed that the total cost of airborne pollutants to vegetation and structures within the US was $4.9 billion per year (DUBOS and WARD, 1972). The role of trees as sinks for carbon dioxide had long been known. As a result in 1991, the US Secretary of Agriculture in a congressional report found that:

The earth's atmosphere is being changed at a rapid rate resulting from human activities, especially as related to the burning of fossil fuels, and the concurrent destruction of trees and forests.

The results of these activities contribute to an increase in the so-called greenhouse gases, especially carbon dioxide.

The preservation and expansion of forests are essential to reduce the rate of build-up of the so-called greenhouse effect.

The risks of global warming are sufficiently great that positive action is warranted to alleviate the potential consequences.

Cities increasingly experience so-called heat island effects as a result of human activities that produce heat and the absorption and retention of heat by buildings, pavements and other portions of the built environment.

Trees, when properly placed around urban buildings, have been shown by research to be effective at ameliorating the so-called heat island effects, offering a low cost way to reduce air conditioning needs which will in turn reduce carbon dioxide emissions from electricity generation.

An urban tree is fifteen times more effective than a forest tree at reducing the build-up of atmospheric carbon dioxide through the 'oasis effect' of cooling urban heat islands, and to sequester directly the amount of carbon saved by the planting of 1.5 billion forest trees.

Reducing atmospheric carbon dioxide by one pound through tree planting costs about 0.3 to 1.3 cents, while through improved appliances costs about 2.5 cents and through more efficient cars costs 10 cents.

Studies have shown that urban trees are disappearing and that approximately four trees are dying for each tree planted in most cities.

Enormous opportunities exist to plant energy efficient trees in urban areas such as 100 million spaces near residences or small commercial buildings and another 60 million spaces along streets as well as parks and other open spaces.

To achieve the maximum benefits from trees, public education, technical assistance, research and incentives to plant more trees will be required.

The American Forestry Association has initiated Global Relief, a public information and education campaign to encourage tree planting, and better forest management nationally and internationally with the initial goal of planting 100 million trees in cities in 1992 to capture the benefits of trees for energy conservation (ANONf, 1991).

The production of valuable scientific models for use in the assessment of global pollution problems and the cost versus benefits of vegetation alleviating these problems has undoubtedly fallen behind the development of an urbanising planet. The growth in car ownership is a world wide phenomenon and characterises the free market doctrine of western governments. The cold war and national patriotic fervour has also seen non-western governments pour vast sums of financial aid into 'dirty' economic strategies (DUBOS and WARD, 1972), policies often fully endorsed by western governments and financial institutions.

While realising the value of urban trees to the environment, the same trees are under enormous pressures for new development, because of arboriphobic attitudes, as a result of pollution, pest invasion and disease infection and as a result of tree resource management being pressurised by legal precedent to fell and overly prune large trees. (LAWSON and O'CALLAGHAN 1995).

This paper concentrates on the value of trees as buffers of airborne pollutants produced as a by-product of the burning of fossil fuels in the internal combustion engine. It uses as an example the pruning of trees in urban areas of the United Kingdom to prevent negligence claims against local authorities for tree root damage to buildings on shrinkable clay soils. The example illustrates that any policy to prune or remove urban trees must be integrated with local/global initiatives to control pollution and guarantee people's health.

Pollution

Pollution has previously been described as 'substances causing damage to targets in the environment' (HOLDGATE, 1979). The pollutant is generated by a source and travels along a pathway (air, soil water) until it is intercepted by a target. The target can be a human being, an animal, plant or an inanimate structure. Therefore if a pollutant fails to reach a target, is diluted to harmless levels or transformed into a harmless substance, then there can have been no pollution. (BIRTLES and STEIN, 1994). The above is a legal definition and will be invariably judged by modern standards of safe limits of exposure to a particular pollutant.

Vegetation can act as an effective sink for airborne pollutants. (DAVEY RESEARCH GROUP, 1993; McPHERSON *et al*, 1994). The plant may intercept particulates or absorb gaseous pollutants which are then combined with plant tissue and are effectively removed from the pollutant pathway.

Carbon dioxide has been a fundamental part of the earth's atmosphere for billions of years—it is an essential component of photosynthesis, the food making process of plants. Man's activities are increasing the levels of carbon dioxide in the atmosphere and urban trees actively absorb this pollution. It is then assimilated as carbon within the plant, with the by-product, oxygen released into the atmosphere. It is estimated that US urban forests currently hold as much as 900 million metric tons of carbon. (McPHERSON *et al*, 1994).

The leaf surface and other plant parts absorb the gaseous carbon dioxide through stomata. During this gaseous uptake, other atmospheric pollutants are 'dry deposited' within the plant. Once absorbed the pollutants diffuse into intercellular spaces or are absorbed by water films. (McPHERSON *et al.*, 1994).

Particulate pollutants are dry deposited on plant surfaces through sedimentation under the influence of gravity or as a result of impaction by windborne particles. (McPHERSON *et al.*, 1994).

It is well established that atmospheric pollutants can harm plants and lead to damaged metabolism, plant structure and life expectancy. This discussion concentrates on the buffering of pollutants by plants – the value to the environment, rather than the effects on the health of the vegetation.

Various estimates have suggested that in the USA and the UK, 60,000 and 10,000 people respectively die from the effects of pollution annually. Given the likely increases in pollution and the pressure on urban plant communities urgent remedial action is indicated.

Table 1 lists some common airborne pollutants and it will be immediately apparent that the motor car is a primary source. At present there are some 25 million cars in the United Kingdom with an anticipated level of 50 million cars by the year 2025 (READ, 1994). In a symposium of medical researchers, (READ, 1994) seven authors considered the evidence linking vehicular emissions and human health. They concluded 'Vehicular pollutants in Britain frequently exceed international guidelines. There is a growing body of evidence to suggest that at levels experienced in the United Kingdom, these pollutants have significant adverse affects on health.'

Respiratory problems, including increasing asthma, reduced lung function, cough, breathlessness, wheeze, respiratory infection, heart and lung disease, cancer and coronary heart disease are listed as sensitive to pollution levels. The authors expressed an urgent need for more research.

The Legal framework

The emphasis of this paper is on pollution, pollution control and pruning practice in the United Kingdom. Nevertheless, for the purpose of legal definition, it is equally applicable to other member states of the European Union (EU), as the law of the Union will invariably override that of the national parliament. (BIRTLES and STEIN, 1994).

TABLE 1. Health Effects of Vehicle Pollution (READ, 1994).

Pollutant	Source	Health Effect
Nitrogen dioxide (NO_2)	One of the nitrogen oxides emitted in vehicle exhaust	May exacerbate asthma and possibly increase susceptibility to infections
Sulphur dioxide (SO_2)	Mostly produced by burning coal. Some SO_2 is emitted by diesel vehicles	May provoke wheezing and exacerbate asthma. It is also associated with chronic bronchitis
Particulates PM10, Total Suspended Particulates, Black Smoke	Includes a wide range of solid and liquid particles in air. Those less than 10 μm in diameter (PM10) penetrate the lung fairly efficiently and are most hazardous to health. Diesel vehicles produce proportionally more particulates than petrol vehicles	Associated with a wide range of respiratory symptoms. Long term exposure is associated with an increased risk of death from heart and lung disease. Particulates can carry carcinogenic materials into the lungs
Acid aerosols	Airborne acid formed from common pollutrants including sulphur and nitrogen oxides	May exacerbate asthma and increase susceptibility to respiratory infection. May reduce lung function in those with asthma
Carbon monoxide (CO)	Comes mainly from petrol car exhaust	Lethal at high doses. At low doses can impair concentration and neuro-behavioural function. Increases the likelihood of exercise related heart pain in people with coronary heart disease. Many present a risk to the foetus.
Ozone (O_2)	Secondary pollutant produced from nitrogen oxides and volatile organic compounds in the air	Irritates the eyes and air passages. Increases the sensitivity of the airways to allergic triggers in people with asthma. May increase susceptibility to infection
Lead	Compound present in leaded petrol to help the engine run smoothly	Impairs the normal intellectual development and learning ability of children

TABLE 1 (continued)

Pollutant	Source	Health Effect
Volatile organic compounds (VOCs)	A group of chemicals emitted from the evaporation of solvents and distribution of petrol fuel. Also present in vehicle exhaust	Benzene has given most cause for concern in this group of chemicals. It is a cancer causing agent which can cause leukemia at higher doses than are present in the normal environment
Polycyclic aromatic hydrocarbons (PAHs)	Produced by incomplete combustion of fuel. PAHs become attached to particulates	Includes a complex range of chemicals, some of which are carcinogens. It is likely that exposure to PAHs in traffic exhaust poses a low cancer risk to the general population
Asbestos	May be present in brake pads and clutch linings, especially in heavy duty vehicles. Asbestos fibres and dust are released into the atmosphere when vehicles brake	Asbestos can cause lung cancer and mesothelioma, cancer of the lung lining. The consequences of the low levels of exposure from braking vehicles are not known

TABLE 2. The Value of Urban Trees—The US Experience

Increases in residential housing prices	With mature trees +7%
Reductions in urban stormwater runoff	With mature trees +10% (conservative estimate)
Reductions in Carbon Dioxide (1)	Mature urban tree 15 times more effective than forest tree at reducing atmospheric CO_2
Reductions in Carbon Dioxide (2)	US Urban forests storing approximately 900 million metric tons of carbon
Reductions in Carbon Dioxide (3)	Energy savings in Chicago due to urban trees +8%
Improvements in air quality (1)	Local air quality improvements with adequate tree cover +10%
Improvements in air quality (2)	In Chicago study area (1991) 6190 metric tons of pollutants removed by trees
Improvements in air quality (3)	Trees most effective at removing PM10, O_3 and CO_2
Improvements in air quality (4)	A large healthy tree removes 70 times as much pollution as a small healthy tree
Combined monetary values for all tree effects (Residential street trees) per annum	$64 per tree
London (England) has 10.4 million street trees	$25.6 million
London (England) has 6 million trees of all types	£2.4 billion

NB The per tree value presumes "healthy" 30 year old trees (deciduous). Older trees with greater leaf surface areas will be more important to the urban environment. The value of London's woodlands is not considered.

Air pollution is the oldest recognised pollution problem with legislation dating back centuries (BIRTLES and STEIN, 1994). Recently the EU has issued directives setting air quality standards for sulphur dioxide and nitrous dioxide, lead and ozone. (BIRTLES and STEIN, 1994) which supplement the Air Quality Regulations, 1989.

The Government is also developing a strategy for legislatively empowering Air Quality Management Areas as part of its statutory requirements under various UK/EU directives. It already continuously monitors five airborne pollutants through its Enhanced Urban Network (EUN) and also rural ozone through the Rural Ozone Network. The recent policy and strategy *Air Quality Meeting the Challenge* states that in future air quality monitoring and action will be the responsibility of local government. (ANONc, 1995) The Department of the Environment is now charged with co-ordinating the legislative, local government and private sector framework within which the Air Quality Standards (AQS) must be applied.

Local authorities working within the above framework will:
(i) have a new duty to review air quality systematically and
(ii) be required to establish Air Quality Management Areas and develop an appropriate remedial plan.

It is submitted that within this structure, the remedial and buffer potential of vegetation should be thoroughly reviewed by arboriculturists working in conjunction with pollution control specialists.

The EU has also been formulating Action Programmes on the Environment since 1973. (BIRTLES and STEIN, 1994); these programmes represent a framework for further discussion and act as a catalyst for initiating environmental legislation. The principles of this initiative include:

'Environmental effects should be taken into account at the earliest possible stage in decision making.'

The acknowledgement that vehicular pollution is a primary source of pollutants is dealt with by controlling fuel as consolidated within the Clean Air Act, 1993 (ANONg, 1993) and through the Road Vehicle (Construction and Use) Regulations, 1986 (ANONh, 1986) which deals with the technologies for controlling emissions from engines. The MOT test now contains a mandatory testing of vehicle emissions and the Department of Transport has powers to stop and test vehicles on the public highway.

Other trends in automotive design tend to mitigate against all of the above regulations. Cars are becoming bigger across many ranges and a major selling point for volume producers is personal safety, air bags, side impact, roll and bull bars all of which make for safe individuals at the expense of total weight and hence fuel economy. The addition of pollution control technology will also add to a car's weight. (ANONd, 1995)

Urban Trees

As well as intercepting pollutants, urban trees have long been identified as providing a wide range of 'benefits' to urban areas. In many parts of the world they play a critical part in combating global warming by reducing the heat island effects of urban centres, reducing the need for air conditioning of buildings and consequently power station output. Predictions for climate change in the UK suggest increased average summer temperatures with drought years increasingly common (ANONe, 1991); air conditioning may become a normal aspect of urban life in parts of the United Kingdom.

Urban trees increase property values significantly (PAYNE, 1978). They offer recreational, aesthetic, conservation/wildlife and educational opportunities and there are strong links with green surroundings and mental/ physical well being. They can screen both sights and sounds. However trees have the capability to affect adversely low rise buildings on shrinkable soils. Trees absorbing water from clay soils change the soils volume which can lead to the subsidence of buildings where the foundations are inadequate to support the load of the building as the clay shrinks. (LAWSON and O'CAL.LAGHAN, 1995). It must be stressed that trees are only part of a very complex problem associated with subsidence and that their ability to damage buildings may have been overstated.

In the United Kingdom insurance carriers have paid out many millions of pounds to the subsidence peril arising from claims by policyholders for damage to their properties. A vicious circle has developed whereby damaged or risk properties have become uninsurable, thus blighting their com-mercial value. The whole problem has been compounded by the alleged role of trees in claims levels and legal actions involving third parties by the insurance carriers against owners of trees accused of contributing to building failure.

The London Tree Officers Association (LTOA) has produced a Risk Limitation Strategy for Tree Root Claims (LTOA, 1995) which puts into perspective the outstanding levels of claims against its member authorities. Between 1986 and 1995 claims stood at £30 million for London spread against 3,500 claims. It is estimated that there are some 1.4 million publicly owned trees in London, many of which are highway specimens and many are in proximity to low rise buildings. Given the predictions for increased summer temperatures and subsequent clay shrinkage, claims may rise.

The LTOA has recommended to its members that a combined policy of cyclical pruning of trees (to stabilise water use and thus reduce soil shrinkage) with removal of certain individual specimens, is the current best practice option for London's publicly owned trees.

Discussion

The immediate conflict facing urban tree managers is that whilst cyclical

pruning may stabilise tree water use, it also removes leaf and green stem tissue. It is acknowledged that the removal of this tissue will stress plants, can lead to a shorter life and may even kill individuals. The scientific basis for supposing it will reduce or stabilise water use is also debatable. It is submitted that by implication; the reduction by anything from 10 to 100 per cent of total leaf area removes the majority of the tree's capacity to act as a target on the pollutant pathway and that by definition the pollutant will then strike at other targets, namely man, animals and buildings. Figures 1 to 3 illustrate pruning cycles between 10 per cent green tissue removal to 100 per cent favoured by urban tree managers. At its extreme there can be no doubt that the tree's water use will be reduced. If allowed to regenerate new tissue, the tree will very quickly recreate the soil water deficits, mimicing the growth phase and water use of the juvenile tree which may far exceed the previous soil drying of the mature plant.

Across many parts of the United Kingdom a programme of pruning is currently in place which will dramatically reduce the total leaf surface area of thousands of highway trees acting as a buffer between vehicle emissions and the environment.

The pruning programmes are often in excess of that recommended by LTOA (LTOA, 1995). The severity of the initial pruning and the frequency of the pruning cycle, will lead to trees becoming stressed as photosynthesis is reduced, removing the trees ability to produce carbohydrates. The remaining tissue will be a target for increasing pollutant levels further stressing the tree.

Pruning in excess of 30 per cent of the green tissue area is not specified within the British Standard for Tree Work BS 3998 (BSI, 1989). It is acknowledged as poor practice by the Arboricultural Association, the Arboricultural Advisory and Information Service and the International Society of Arboriculture who all advise that over pruning is bad practice, leading to a shortened life, tree hazard and a loss of amenity.

The legal position suggests that professionals should rigorously follow the best practice guidelines of their profession, even if a minority interest suggests otherwise. (see *NcNair, J Bolam v Friern Hospital Management Committee (1957) 2 A11 E.R.118)*. The California state legislature has passed a law (Government Code section 53067) which states 'Topping is the practice of cutting back large diameter branches of a mature tree to stubs and is a particularly destructive practice. It is stressful to mature trees and may result in reduced vigour, decline or even death of trees. In addition new branches that form below the cuts are only weakly attached to the tree and are in danger of splitting out. Topped trees require constant maintenance to prevent this from happening and it is often impossible to restore the structure of the tree crown. . .'

One reason that the practice of over pruning may have developed is legal precedent. The courts, while acknowledging that tree root claims must

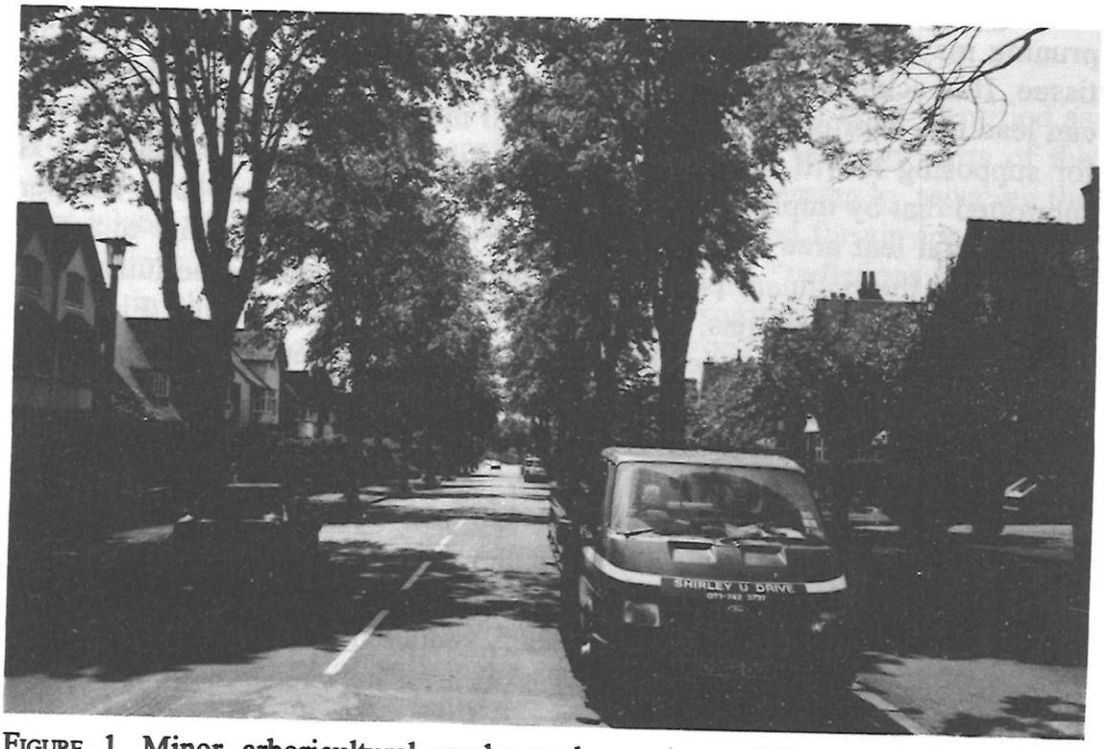

FIGURE 1. Minor arboricultural works such as crown lifting and thinning are unlikely to have any measurable impact on subsidence claims.

FIGURE 2. Sensitive pruning, in accordance with the principles of BS 3998, is useful in limiting liability only in so far as it suggests "active management".

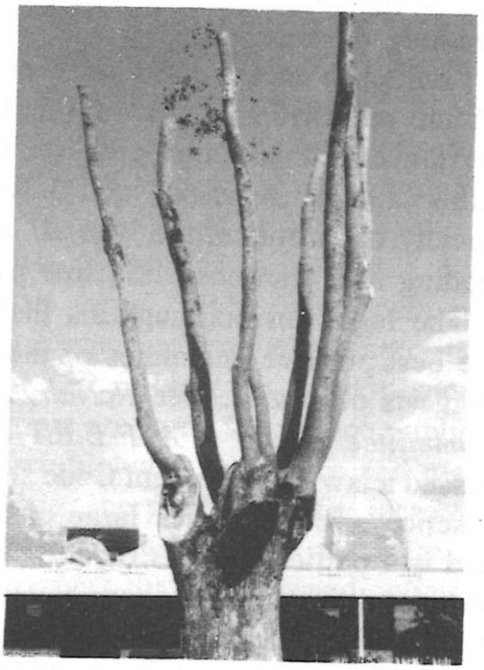

FIGURE 3. We can only hope that this is not the likely future of our urban tree stock.

contain an element of foreseeability, are poorly advised. (*J Toulson Patterson v Humberside County Council ECGS 39 (1995)*). The paucity of arboricultural principles, the misuse of that which is available and the production of misleading practice notes by related industries and professions have all combined to produce a climate of distrust in relation to urban trees.

Highway tree managers who believe that a 30 per cent reduction is the best practice may further compound the issue by advocating that a 50 per cent plus reduction will be better practice. The advice that overpruning kills trees or significantly shortens their life is not being accepted.

The use of geotextile root barriers, tree growth regulators, selective tree removal and replacement and education of the insurers, public and allied professions is not being investigated, exploited or attempted.

Conclusions

Airborne pollution and its management, is and will remain one of the major challenges facing the public and private sectors attempting to secure urban sustainability. Air pollution kills thousands of people and blights the lives of millions of others. Urban trees can very effectively add to pollution control and energy management programmes. They act as effective sinks for gaseous and particulate pollutants, they cool heat islands reducing pollution production and energy use at power stations. Urban trees offer a wide range of other benefits, including water management, increased land values, aesthetic, wildlife and conservation and education opportunities.

The problems associated with shrinkable clays and building failure are real. A single policy of overpruning to control tree water use will remove all of above advantages of urban trees, complicating programmes to achieve sustainable cities. Investigation of tree growth regulators, geotextile root barriers, alternative pruning practices/regimes may allow maximum leaf surface area with minimum risk potential for owners and insurers of low rise buildings.

Further research into the potential for the development of urban forest ecosystem and climate management models could be well supplied with existing data. Beneficiaries of this approach would be building, life and health insurers, city managers, urban and rural dwellers, national and European governments and other interested agencies

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