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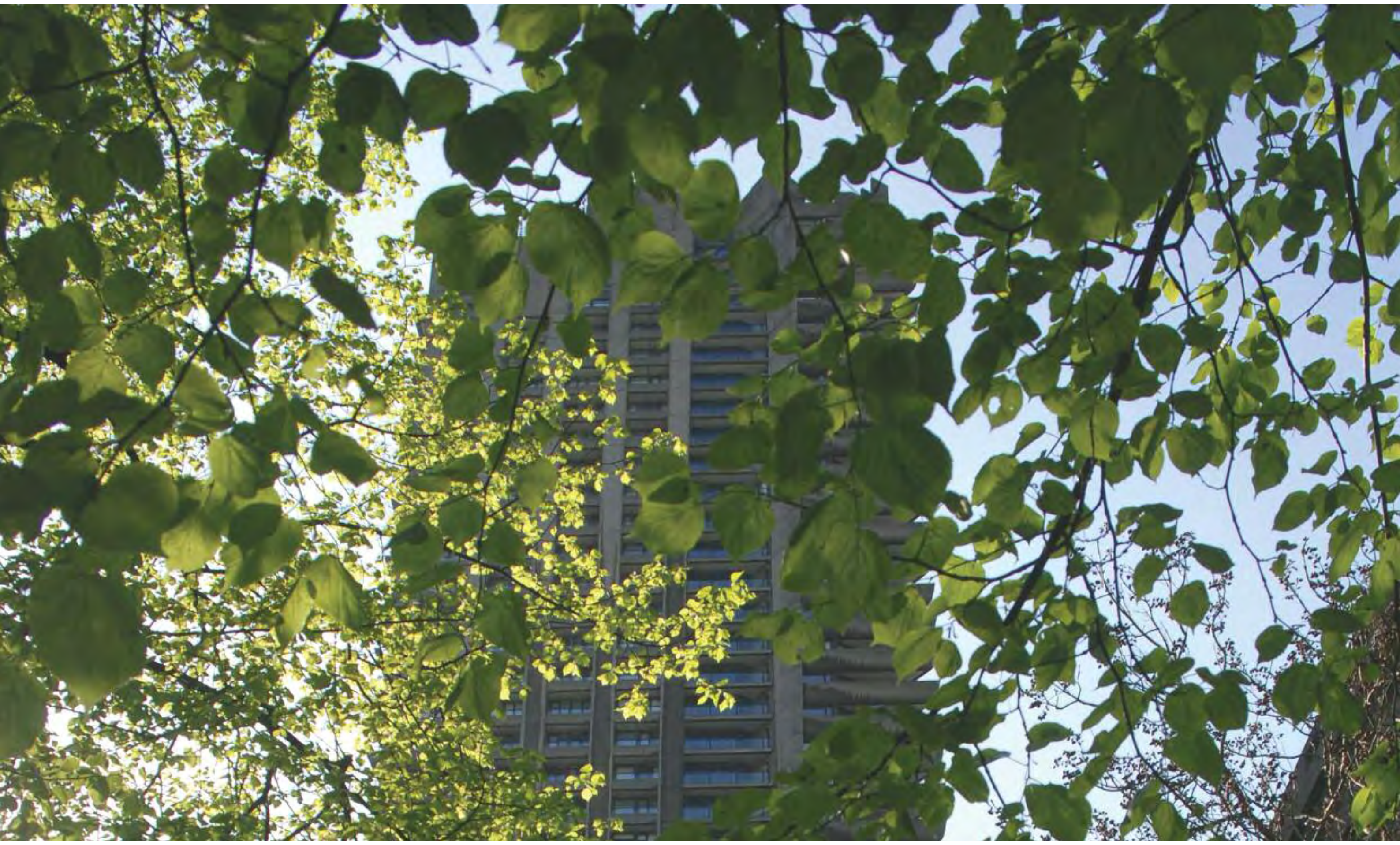

Research Report

# Trees, people and the built environment

## Proceedings of the Urban Trees Research Conference 13–14 April 2011

Institute of Chartered Foresters

Forestry Commission

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## Proceedings of the Urban Trees Research Conference 13–14 April 2011

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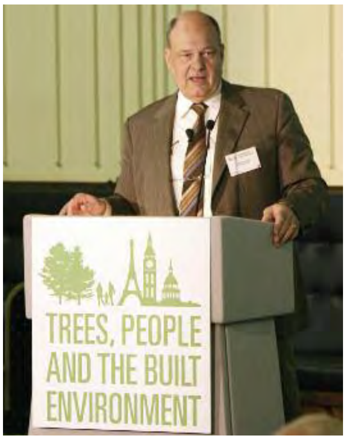
# Introduction to the Conference




Our urban forests, the trees and woodlands in and around our cities, have a vital role to play in promoting sustainable communities. As the most important single component of green infrastructure these trees can provide numerous environmental, economic and social benefits, contributing enormously to the health and welfare of everyone who lives and works in the urban environment. As concerns grow about the quality of the urban environment in many towns and cities throughout the world, the importance of protecting and expanding our urban forests can only increase.

Urban forestry itself can be defined as a planned, systematic and integrated approach to the management of our urban trees and woodlands. It was a desire to emphasise that third element, the integrated approach, which was the initial driving force behind the development of this conference. Let me explain the background.

Back in the 1980s and 1990s, a series of Arboricultural Research Conferences were held in Britain, supported by the Forestry Commission. I was fortunate to attend some of those events along with many tree officers, tree consultants, academics, researchers and others. Although widely regarded as providing arboriculturists and some landscape practitioners with highly relevant information about current research on both urban and rural trees, for some reason they did not continue. However, in those research conferences and in many other arboricultural events I have attended in recent years, there was one fundamental weakness. Invariably at these events, it was just 'tree people' talking to ourselves. Those professionals who really had such an impact our work – the landscape architects, engineers, surveyors, architects, ecologists, conservationists and others – were just not there or at least very thin on the ground.

I have always been keen on the idea of resurrecting those early research conferences but this time with some crucial differences. After sharing my thoughts on this with a few close colleagues, a small group of us decided to make our ideas a reality. Right from the outset, we agreed on two crucial points about our proposed research conference. First, we believed the focus should be specifically on urban trees, to reflect the vital role that our urban forests can play in creating healthy and sustainable town and cities. The conference would 'showcase' the very latest research on the subject of urban trees and the management of the urban forest. Secondly, and most importantly, we needed to reach out to all those other professionals, apart from arboriculturists, that have such a major impact on the urban forest. Fortunately, the recently formed Trees and Design Action Group (TDAG) had already made a significant start down that road by providing a forum where natural and built environment professionals could engage with each other on issues relating to trees in the urban environment. Building on TDAG's established contacts, we invited a wide range of relevant organisations to nominate representatives to join a steering group to lead the development of the proposed conference.

The first meeting of the Conference Steering Group took place in Birmingham in January 2010 attended by 12 representatives of relevant professional bodies and other organisations. There was considerable enthusiasm for the idea of the conference from all present and some very useful suggestions on how to develop the research aspects of this. However, there was no consensus on how the event could be organised or when it could be held. After the meeting, support for the proposed conference continued to grow rapidly but no individual organisation appeared keen to take a lead and offer substantial material support to ensure it would happen. It was at this point that the Institute of Chartered Foresters (ICF) stepped forward. The then President of ICF, Bill MacDonald, was quick to recognise the importance of holding this conference, and the value of the partnership of organisations that had already agreed to support it. Consequently, ICF made an offer to the Steering Group to host the event as its National Conference for 2011. The Steering Group would continue to be responsible for deciding the conference programme and other academic aspects of the event, while ICF would provide the administrative and other support required. The Steering Group readily agreed to this proposal.

Another important factor in enabling the Steering Group to deliver the conference was the early and significant support of the Forestry Commission. Not only did it play a crucial role in facilitating the event itself, it also undertook to publish the conference proceedings, thus ensuring that there would be a permanent record of all the vital research that was being presented.

We were also fortunate in gaining support for the conference from HRH The Prince of Wales, a very prominent champion for trees and a sustainable urban environment. Although HRH was unable to attend the event in person, due to other commitments around that time, he was able to send a very pertinent and personal message of support to the conference delegates.

When the conference was eventually held in April 2011 it was an outstanding success. With nearly 400 delegates, it was one of the largest tree conferences ever held in Britain. Most importantly, the conference achieved its main aim of including the other relevant non-tree professional bodies, particularly from the built environment sector. A number of senior figures from these bodies acted as Session Chair for parts of the conference and there were a significant number of their members as delegates.

The success of the conference was due to the efforts of many different organisations and individuals, and too numerous to mention everyone individually. However, I want to thank the members of the Conference Steering Group who represented the various partner organisations. Without their support, commitment and hard work, we would not have been able to maintain that unique partnership of relevant organisations. And without their efforts to promote the conference to their members we would not have had anything like the number of delegates we achieved.

On behalf of the Conference Steering Group, I want to thank the ICF whose vision and leadership in offering to host the event was pivotal in ensuring it actually happened. In particular, we want to thank Allison Lock and her team at ICF for the very professional way in which they delivered the organisational aspects of the conference. For many of those attending, this was their first experience of an ICF organised event and a great many subsequently commented on how well the event reflected on the standing and professionalism of the ICF.

Lastly, on a personal note, I want to thank two individuals who played a vital role in the success of the whole conference. They are Keith Sacre of Barcham Trees and Sue James of TDAG. Without their enthusiasm, commitment and expertise, much of what we achieved would not have been possible. They not only played a crucial role as members of the Steering Group, they also gave me invaluable support and encouragement at those times when I was in danger of being overwhelmed by the task of 'keeping the show on the road'.

There can be no doubt that this urban trees research conference was a remarkable success. The event itself and the quality of the papers in the conference proceedings are testament to that. However, ultimately, it should be judged on what lasting impact it has on developing a more integrated approach to the planning and management of our urban forests. An excellent start has been made but everyone involved in the conference must ensure that those gains are consolidated and built on. One way might be to organise another research conference in the future. Another is to support the continuing work of TDAG.

**Mark Johnston**

Conference Chair and Chair of the Conference Steering Group

# Message to delegates from HRH The Prince of Wales

CLARENCE HOUSE

I would first of all like to say how very sorry I am not to be with you for this crucially important conference. Throughout the world, trees are a life-giving resource and, when you consider the Rainforests – teeming with species often unknown to humanity – it is easy to see why. However, far too few people seem to consider the importance of trees within the urban environment.

Urban forests provide us with numerous environmental, economic and social benefits and contribute enormously to the health and welfare of everyone who lives and works in the urban environment. They have a particularly vital role as part of the development of truly sustainable communities.

For many years I have believed that urban planners should consider trees as an integral part of any development and I have tried to pursue this approach throughout the Duchy of Cornwall, whether at Poundbury, Newquay or elsewhere. Our experience has shown the benefit of designing new trees into the scheme from the outset, so that services can be diverted well away from roots, giving the trees a chance to thrive. This also reduces the necessity of providing elaborate and expensive subterranean tree planters. Also, with the increasing prevalence of diseases, it is important to select the appropriate species of tree for a particular area, and this is where the skills of the arboriculturalist are especially relevant.

Your conference is desperately important as it brings together, for the first time in Britain, all the relevant professional bodies concerned with trees, landscape and the built environment. As you know far better than me, the protection and expansion of our urban forests requires a truly integrated approach. Too often, over-complex bureaucratic processes can make it difficult, if not impossible, to plant the variety and number of trees our urban areas really need. To overcome this inertia, it is vital that we ensure as many people as possible understand the true value of urban forests. I am, therefore, delighted to see that you will be learning about the ecosystem benefits from urban trees in Torbay, as well as discovering how New York City has used research to justify its important "Million Tree" programme. New Yorkers are unashamedly making the case that planting trees is one of the most cost-effective ways to help support the local economy, through cleaning the air and improving property prices. There is surely much that we can learn from their experience…

In a fast-moving metropolitan environment it can be easy to forget the relevance of arboriculture. It can seem quaint to suggest that simply planting more trees can provide answers to many of the challenges facing towns and cities, but I am sure you all agree that it is in fact by embracing the value of natural solutions that we will make lasting progress.

This brings you all my very best wishes and I much look forward to hearing the results of your deliberations.

HRH The Prince of Wales

Charles

# Opening address


I'm really, really pleased to be here because this is heart and mind stuff for me. When I spoke at your [the ICF conference] dinner last year, I said I believe that we've got a huge opportunity if collectively we pull together around this environmental agenda, across the sector. Forget our differences and play to our strengths. Try and influence the way people are thinking so that they buy-in to the importance of trees in society, to the importance of diverting funding to make sure that we have a greener world – a better world to pass on to our kids.

Well, 12 months ago who would have thought we'd have had the few months that we've just had? Who would have thought that trees, forest and woodlands would have been front page, the biggest item in any MP's mail, interviews right and left and centre. The passion of the people coming through? Who would have thought that we'd have seen people collecting together in really cold conditions in their thousands to make their point and say: 'trees, woodlands and forests matter to us'? Who would have thought that forestry would be the debate around bars and coffee shops as well as around Westminster to the extent that it has been? Who would have thought that we could have ignited that degree of passion in a nation around our trees?

I'm so pleased that that happened. I'm delighted that the nation spoke. It was the start of a conversation, but it was also only the beginning, because for me one of the really important outcomes that has to come from that sort of national focus is the change in what we spend our money on, in our personal lives, in our everyday lives, in our working lives, and at a national budget level.

For me, what really matters is that we don't only think of our heritage forests – really important though our heritage forests are, though I defy you to define that – but also about those woodlands, and those trees in our parks, on our streets, and on the edges of our towns and cities. They are the heritage woodlands for the people that live there. Where was the debate around that? I didn't hear much of it.

I think what I'd like to hear at the end of these two days is a consensus in the room that we are going to cruise on that fabulous wave of national support that we have for woodlands, trees and forests and push it like mad, personally and professionally, to make sure that this is a watershed moment in how we think about our environment and trees within that environment from now on.

I come from the north of England, you can tell. I've worked with people in the Mersey Forest and the Red Rose Forest, and very recently in the White Rose Forest. I used to be a leader of a council pressing for more green spaces in our towns before it was fashionable to do that.

I also used to be the Chair of a health trust which made me passionate about the work that we are doing at the Forestry Commission with the NHS Forest, to make sure that our health centres are also environmental health centres. That the charitable monies held within those fabulous institutions aren't only spent on what's happening inside, but what's happening outside.

I chair something called 'Incredible, Edible Todmorden'. I have to mention that. We want more orchards. We want all our schools to have trees surrounding them. We want to make sure that every health centre is surrounded by orchards. We want to make sure that every tenant on every estate has access to land to grow what that tenant wants to grow. We want to bring the woodland into the heart of our towns and our cities wherever they might be.

In all these organisations I have seen the importance of the environment to all our lives. At the Forestry Commission I'm terribly proud of the work that we do: the work that we do on education, the work that we do on reconnecting people to our environment, and the standards that we set, and help others to work to, to make sure that we are delivering sustainable woodland and forestry management across the piece.

We're not going to stop doing that. That is our core business. To make sure that we work effectively in the future in partnership across our public forest estate so that those wonderful woodlands and forests that people stood up and were counted for are maintained in perpetuity for our children and continue to deliver the public benefits that they do today.

We will continue to do that but, more and more, we need to have a dialogue with many more people across the length and breadth of this country. It's really important that we take the message about rethinking investment plans, rethinking management plans from the very heart of our cities right out into our deepest countryside, beyond the bodies represented in this room today.

Whilst we're here together, environmentalist, tree people, we get a real buzz. We think it's really funky, and that most people think the environment is great. Well that's not how the world is because there's a load of people out there who don't share our passion. There's a load of people out there who have a deficit to deal with. There's a load of people out there who've had to make a lot of people redundant. There's a load of people who think there are more important things to deal with than trees. We need to show them that the environment and these difficult challenges are not mutually exclusive.

We'll be hearing lots today about examples all over the globe where passion for trees on our streets in our towns and cities can lead to a better understanding of the environment, and that's what we need. More people understanding environmental wellbeing equates to their own wellbeing. If there's one thing that drives me at the moment, it's not the aesthetic; it's the survival of this planet.

At the end of the day we need ideas of how we can inspire more people from tenements, from our villages, our hamlets, from the Manchesters, the Birminghams and the Cardiffs of this world, to get the importance of their environment. I would like people to sign up to a 38 Degree poll that asks what are we doing about climate change? What are we doing about investing in the smartest, greenest resource we have? How will we make a difference to our kids' futures?

What are we actually doing about that? Taking the heart, marrying it with the minds and creating a drive and a movement that says collectively we have a real opportunity to make a difference to our quality of life, not just today, but tomorrow.

We all know that trees, woodlands, forests, orchards, whatever they might be, have a fabulous impact on the way we feel. We're mapping happiness at the moment. Did you hear about that the other day: 'mappiness'? It's really great. You map how people feel in different areas and then you ask: 'What sort of area was that?' Do you know when people feel great? When they see trees, when they're in forests, when they're in woodlands, when they're in parks. That's when they feel great. It might sound a bit tree-huggy for some of you in this room, but the thing for me that's important is that David Cameron [Prime Minister] thinks it's great, and that's good.

We need to recognise that and not be too snobby about it. Recognise that we need a hook into mappiness when we're telling our story. What we are missing is that drive and passion at a grass roots level over and beyond the 38 Degrees. People don't live their life in silos. If they feel good about something, if they feel great about a product, that'll affect their spend. If something makes them happy and they want to repeat that experience, that will change what they vote for, and what they vote for will allow us to put the environment centre stage, and have the sorts of uplift that Professor Read in his report on climate change demands of us, of all of us. It's not, 'well I would if I could but I'm really pressed at the moment'. While our personal circumstances are being challenged, the planet, the ability for us to survive, our environment, is slipping through our fingers.

So, what really matters is we listen to the people. We see the opportunity to build on that passion. We extend that dialogue collectively with them. We help them to see it's not just about the heritage forest, but it is about the woodlands and it is about the town centre places, and it is about the community forest.

And it's not all about money. I have never worked in a public body – and I've worked in them for 20 years – that ever had any money whether it was a local authority or whatever. Of course it was really hard, but it was also great because I would say to somebody, what would be really fabulous is if you came along with me and I used a bit of your budget and you used a bit of my budget and that led to us thinking differently. We each gave a little bit, and we got a really creative solution.

I need to see change. We need to see change. We know everything we need to know about what needs doing. We just need the will to do it.

So, for me, what's really important today is that you, the ICF, have had the leadership and the foresight to bring together people from a range of backgrounds whose common focus is their passion and their knowledge and their experience about trees and their importance and how to manage them sustainably.

We are, in this room, one sector. We need to talk with one voice. We need to be clear what our message is to those with influence. We need to be clear how we are going to communicate that message to the general public. We have the advocates in this room. Some can do it at a government level. Some can do it in an area forum. Some can do it at planning committee. There's all sorts of champions in this room. We need during the course of the next two days to find the mechanisms to allow them to function, to allow them to inspire, to allow them to make the difference.

I believe that we can do it. I believe we have to do it. I think we have examples of great practice all over the place that instead of just packing and putting on a shelf, we need to share proactively.

There's no certainty in these things, but the one thing that is certain is that we cannot miss the opportunity to come up with some really positive messages at the end of these two days. To say: 'Do you know what they're doing in New York, know what they're doing in Canada, why can't we do that? I'm going to go back and speak to the leader of council or the chair and do something about that'. If we missed that opportunity to really raise our games individually, then collectively we will have let a truly historic moment slip through our fingers.

There are several programmes at present that can help us. We've got the Woodland Carbon Task Force looking at ways of getting more investment in our woodlands. We've got The Big Tree Plant. So needed, but also so in need of funding.

We've got the Independent Panel on Forestry. I'm a big fan of the Independent Panel actually. That might seem a strange thing for me to say, but I believe we have an important platform in the panel to raise the profile of trees again and help continue the public dialogue we all want. And I think we stand a chance of having some really interesting recommendations that we can start to work on together.

So, well done for calling this conference together; it's been a long time in the coming.

The Forestry Commission has been through the mill, as have many of you in this room in the last few months. But we are as committed and as passionate as we always have been to make sure that the importance of trees becomes centre stage in people's lives, and that the knowledge that we have and the experience that we have is shared collectively, not just on the Forestry Estate but throughout the sector. Not just with traditional friends, but through the International Year of the Forest with a much broader church. I am committed to make that happen.

From local government countryside officers, landscape planners, foresters, from deliverers of community forests, from politicians to policymakers, without you standing up and being counted on this issue, it simply won't happen.

What I said last year is: 'I'm up for it if you're up for it'. If you want to make a difference, want to have your messages heard, I want to help you deliver those. We *can* deliver those. It isn't politically contentious. It's a survival plan. So, let's get on with some great futures, and let's make sure that we see this as the watershed moment that it is.

Thank you very much.

**Pam Warhurst**

Chair, Forestry Commission

# Using urban forestry research in New York City


## Abstract

Until recently the benefits of trees were well known but not well defined or quantified. The US Forest Service has released a number of exceptional analytical tools that allow urban forest managers to generate dollar figures for the benefits being generated by their city or town's trees. The New York City Department of Parks & Recreation (NYC DPR) successfully used two of these tools, Urban Forest Effects Model (UFORE) and Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM) to calculate the benefits provided to New Yorkers by the estimated 5.2 million trees in the city.

These figures persuaded Mayor Bloomberg that trees should be a vital component of PlaNYC, his plan for a greener, greater New York. Initiatives involving trees are included in three of the plan's five key policy areas for the urban environment. Trees have instrumental roles to play in greening the landscape, cleaning the air, reducing energy use and capturing stormwater. Consequently, PlaNYC led to massive increases in the urban forestry budget as NYC DPR is tasked with planting 220 000 streets trees and reforesting 809 hectares of parkland. Aside from justifying greater urban forestry resources, research has also played a crucial role in setting policy and directing programming to ensure that these resources are deployed to maximum effect.


## Introduction

Urban forestry managers have continually strived to find the precarious equilibrium between the needs of trees and the needs of people. Often the pressures of liability and limited resources have forced these managers to focus solely on tree maintenance and tree removals. There has been some excellent research completed in the fields of tree mechanics and hazard tree evaluation. This research has been coupled with numerous studies on the social and psychological benefits of humans interacting with their natural environment. However, this arboricultural and social research has a limited use for urban forest managers battling to holistically manage a diverse resource at a city or town level. Only recently have urban forest managers had more to help them secure funding and guide urban forest programming.

The US Forest Service has recently released a number of free useful tools for urban forest managers. These tools allow urban forest managers to quantify the annual environmental benefits provided to their town or city by their urban forest. These quantified environmental benefits have allowed policy makers to understand and appreciate the urban forest. These tools have very much put trees on the policy map.

The New York City Department of Parks and Recreation (NYC DPR) has used two of these tools to analyse the city's urban forest. The Urban Forest Effects Model (UFORE) calculated the environmental benefits of the entire urban forest, while the Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM) focused solely on the street tree population. NYC DPR coupled the results of these tools with other pertinent research to justify the inclusion of trees into Mayor Bloomberg's sustainability plan for New York City (NYC) called PlaNYC. In PlaNYC, trees play a major role in greening the landscape and are also being actively deployed in helping to capture stormwater and cleaning the air. Their inclusion was only possible through NYC DPR being able to prove and quantify the annual environmental benefits provided by them. However, the research did not only justify why additional resources should be allocated into the urban forest. This research also provided key information that allowed proper attainable urban forest goals, policies and strategies to be established to maximize the benefits of New York's urban forest.


**Keywords:**

benefits, PlaNYC, quantify, STRATUM, UFORE



**Matthew P. Wells**

Central Forestry and Horticulture, New York City Department of Parks & Recreation, USA

This paper will look at the key research studies and how they have been used to justify and focus urban forestry programming in NYC. Alongside this central theme will be the importance and power of in-house collection of administrative data and its analysis. NYC DPR has very successfully used in-house resources, volunteers and interns to help perform vital research.

## The social value of the urban forest and urban trees

The social value of the urban forest has been well researched, although these studies have not been able to quantify this value in dollars. It is understood that views of trees and nature are known to help improve mental wellbeing (Kaplan and Kaplan, 1989) and also help with recovery from illness (Ulrich, 1984). It has been shown that humans derive pleasure from trees (Lewis, 1996). Other research has also shown that outdoor spaces with trees facilitate greater interactions among local residents, which improves neighbourhood socializing (Kou *et al.*, 1998). This research is fascinating and very valuable and reinforces what many of us have always instinctively believed about trees and the urban forest. However, these social values alone do not provide the strongest justification or argument for urban foresters trying to preserve existing trees or find resources to plant new ones, especially if liability is also a concern.

Only when more recent research emerged that started to quantify the environmental benefits and the associated financial value provided by the urban forest did trees become an essential element in a city rather than just a feel-good luxury item. A great deal of this research has been done by the US Forest Service (McPherson *et al.*, 2007; Nowak *et al.*, 2007; Peper *et al.*, 2007). They provide a number of free tools for urban forest managers via their i-Tree software suite. Two of these tools, the Urban Forest Effects Model (UFORE) and the Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM), have been invaluable to urban foresters in NYC, especially when combined with other relevant research.

## Research on the entire urban forest in New York City

New York City (NYC) is America's largest metropolis and home to an estimated 8.2 million people (US Census Bureau, 2006). NYC is extremely urban in its environment and even though it is home to one of the most famous parks in the world, Central Park, it is not otherwise known for its trees and open spaces.

### The Urban Forest Effects Model (UFORE)

The U.S. Forest Service completed a UFORE (now called i-Tree Eco) survey and analysis of NYC's entire urban forest in 1996, and estimated that it contained 5.2 million trees (Nowak *et al.*, 2007). This was somewhat of a surprise. Furthermore, the UFORE study put the structural value of NYC's urban forest at $5.2 billion and estimated that 50% of the urban forest fell under the jurisdiction of the New York City Department of Parks and Recreation (NYC DPR). UFORE also estimated that NYC had a 20.9% tree cover, with 42.7% of the trees being over 6 inches (15.25 cm) in diameter. But perhaps the most interesting findings were the environmental benefits the urban forest was delivering to New Yorkers. The urban forest worked to remove 1998 tonnes of air pollution each year at an annual value of $10.6 million and stored 1.22 million tonnes of carbon at an estimated value of $24.9 million. Finally, the urban forest was sequestrating 38 374 tonnes of carbon annually at an annual value of $779 000. It should be noted that despite all this impressive data, the UFORE study acknowledged that additional social and environmental benefits were not included. These key figures about NYC's urban forest immediately provided NYC DPR with a reason to request additional resources for forestry. Ultimately, a federal agency had proved that NYC's urban forest was providing substantial and valuable environmental benefits to the city.

The UFORE report was more that just a report on environmental benefits. It also provided essential data to aid in the correct management of the urban forest. It identified the most common species as being tree of heaven (*Ailanthus altissima*) at 9.0%, black cherry (*Prunus serotina*) at 8.1% and sweetgum (*Liquidambar styraciflua*) at 7.9% (Nowak *et al.*, 2007). It also confirmed what many already assumed, that large-canopied trees, provide the greatest benefits, with ironically the London plane (*Platanus* x *hispanica*) having the greatest importance in NYC based on total leaf area and abundance. UFORE also helped us understand the potential threat of the invasive Asian longhorned beetle (ALB) to NYC. ALB was discovered in the NYC borough of Brooklyn in 1996 and this was actually the first time it had been discovered on the US mainland. ALB is a beetle that destroys certain species of trees through boring damage. UFORE concluded that 43.1% of the urban forest was potentially at risk from ALB. This knowledge made federal, state and city agencies very aware of the implications of ALB for NYC as $2.25 billion worth of trees were potentially at risk.

## Urban tree canopy coverage

In April 2006, NYC DPR commissioned the US Forest Service and the University of Vermont's Spatial Analysis Laboratory to conduct an analysis of urban tree canopy (UTC) coverage in the city. NYC DPR wanted to understand if achieving an UTC goal of 30% by 2030 was possible. The completed research established that 24% (17 972 hectares) of NYC's total land area was already covered by UTC (Grove *et al*., 2006). The study also calculated that 42% (32 052 hectares) of the city's total land area had the potential to be covered by UTC because no roads or buildings were present. The report concluded that a goal of 30% UTC by 2030 was achievable if 4856 hectares were added. The report also recommended that progress towards attaining this UTC goal should be monitored by using remote sensing at five-year intervals.

# Research on street trees in New York City

Street trees are perhaps the most visible and easily defined component of any urban forest. They are the trees outside people's homes and places of work that touch their lives on a day-to-day basis. Street trees therefore usually require the most intensive management by urban foresters and their location tends to make them the ones that people are most interested in for either positive or negative reasons. They are the public face of trees.

## The 2005–2006 street tree census

Every decade the NYC DPR undertakes a census of the street tree population. The last census undertaken in 2005–2006 was called 'Trees Count'. The census was conducted with the help of more than 1100 volunteers logging over 30 000 hours (New York City Department of Parks & Recreation, 2007). This level of participation represented a 57% increase from the previous census in 1995–1996 where only 700 volunteers participated. Volunteers were required to attend a three-hour training session and collected 42% of the census data. The remainder was completed by in-house staff and by an urban forestry consultant.

The census collected over 15 million pieces of data across the five boroughs. To facilitate the data collection, the city was divided into 1649 survey zones that were assigned to the individuals taking part in the census. For each tree counted, the surveyor recorded information such as location, species, diameter at breast height (dbh), condition, tree pit type, soil level, sidewalk condition, presence of overhead wires and infrastructure conflicts. Survey results were reported back to NYC DPR using an interactive census website application or on paper.

The published results of the tree census identified 592 130 street trees in NYC; this represented a 19% increased from the census a decade earlier (New York City Department of Parks & Recreation, 2007). London plane was the most prominent species making up 15.3% of the population with Norway maple (*Acer platanoides*) not far behind at 14.1%. Other important species were Callery pear (*Pyrus calleryana*) at 10.9%, honey locust (*Gleditsia triacanthos)* at 8.9% and pin oak (*Quercus palustris*) at 7.5%. This data immediately highlighted that NYC needed greater species diversification and no one species should really exceed 10% of the total population (Peper *et al*., 2007).

Table 1 shows the tree condition results of the census and Table 2 shows the size of the trees. The census data provided a good snapshot of the entire street tree population within a relatively small time band. This is not achieved when surveying a portion of the street tree population on an annual basis over multiple years.

**Table 1** Tree condition results of the 2005–2006 tree census (New York City Department of Parks & Recreation, 2007).

| Tree condition | Percentage of the population |
|---|---|
| Excellent | 23.9% |
| Good | 66.4% |
| Poor | 8.3% |
| Dead | 1.4% |

**Table 2** Tree size results of the 2005–2006 tree census (New York City Department of Parks & Recreation, 2007).

| Tree size | Percentage of the population |
|---|---|
| Small (0–15 cm) | 25% |
| Medium (15–46 cm) | 50% |
| Large (46–76 cm) | 20% |
| Extra large (over 76 cm) | 5% |

Other interesting information that came out of the census was that 15% of the tree population suffered from trunk wounds and 5.3% had a cavity of some type. Finally, the census highlighted some of the key conflicts that NYC's tree population has with infrastructure (see Table 3).

Table 3 Trees with urban conflict results of the 2005–2006 tree census (New York City Department of Parks & Recreation, 2007).

| Urban conflict | Number of trees | Percentage of the population |
|---|---|---|
| Overhead wires | 209 171 | 35.8% |
| Raised sidewalks | 100 829 | 17.3% |
| Cracked sidewalks | 65 299 | 11.2% |
| Close paving | 43 409 | 7.4% |
| Choking wires | 13 865 | 2.4% |
| Choking guard/grate | 3918 | 0.7% |
| Tree lights | 3918 | 0.4% |

Table 4 Number of trees recorded per borough in the 2005–2006 tree census versus 1995–1996 (New York City Department of Parks & Recreation, 2007).

| Borough | 1995–1996 census | 2005–2006 census | % increase |
|---|---|---|---|
| Bronx | 47 995 | 60 004 | 25% |
| Brooklyn | 112 400 | 142 747 | 27% |
| Manhattan | 45 793 | 49 858 | 9% |
| Queens | 217 111 | 239 882 | 10% |
| Staten Island | 75 171 | 99 639 | 33% |
| **Totals** | **498 470** | **592 130** | **19%** |

The number of trees impacted by urban conflicts in NYC is considerable (Table 3). Therefore, mitigating these street tree conflicts with infrastructure, as far as reasonably possible, is a key challenge for NYC DPR. The census recorded that nearly 36% of the population was under wires and could be subjected to utility clearance pruning. The census also identified that 17.3% of the trees surveyed had raised adjacent sidewalk and 11.2% of the population had cracked adjacent sidewalk. In NYC property owners are responsible for the maintenance of the sidewalk adjacent to their land (New York City Department of Transportation, 2008). Damaged sidewalks and the disturbance of utility wires are often cited as a reason for requesting removal of a tree or protesting against the planting of a new one. The authors of recent research analysed complaints to NYC DPR about the placement of new tree planting. A total of 33% of these complainants objected because of the potential of the tree to cause utility service disturbance and 14% objected because of the potential of future sidewalk damage (Rae *et al*., 2010). These are obviously both significant factors when considering urban forestry programming and the concerns of property owners.

The tree census data allowed NYC DPR to consider their street tree inventory at a borough level and the change in that inventory since the census in 1995–1996 (Table 4).

The census clearly showed that certain boroughs had considerably more trees than others, as detailed in Table 4. It can be seen that Staten Island had the greatest rise in its street tree population since 1995–1996 with a 33% increase. Manhattan had the least with just a 9% increase and Queens was not far behind at only a 10% increase. The census data also identified that London plane was the most common species citywide, but is only the dominant species in Brooklyn (24%) compared to honey locust in the Bronx (13%) and Manhattan (23%), Callery pear in Staten Island (25%) and Norway maple in Queens (18%) (New York City Department of Parks & Recreation, 2007).

The tree census also identified other borough trends in tree health and infrastructure conflicts. The Bronx's tree population was in the worst condition, with 12% of trees falling into the dead or poor condition categories, followed closely by Manhattan at 11.3% and Queens at 10% (New York City Department of Parks & Recreation, 2007). Staten Island's trees were recorded as being in the best condition with only 6% of trees falling outside the good and excellent tree condition categories. As stated previously, 36% of the total citywide tree street population was recorded as being under utility wires. However, when we look at this percentage at a borough level, it rises significantly to 48% in Queens but falls back to 23% in Staten Island and is lower still in the Bronx at 12%. In summary, management policies should account for the distinct differences in the urban forest even within a single city or town.

## Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM)

STRATUM (Street Tree Assessment Tool for Urban Forest Managers) is now known as i-Tree Streets and is another application available from the US Forest Service. STRATUM uses street tree inventory data to calculate the annual environmental and aesthetic benefits generated. It is distinctly different from UFORE because it does not consider the urban forest in its entirety. The STRATUM model is more accurate in its results compared to UFORE because the size, species and condition of each and every tree is known. It is possible to perform a STRATUM analysis using just a sample of the street tree population (Kling, 2008), although this was not done in NYC. The quantified benefits calculated by STRATUM include energy conservation, air quality improvement, carbon dioxide reduction, and stormwater catchment. The model also looks at the aesthetic contribution of street trees in terms of increasing property value.

STRATUM analysis for a city could cost more than $100 000 to survey and analyse growth data for 800 trees (Kling, 2008). So that this cost would not be prohibitive, the US Forest Service split the USA mainland into 16 climatic zones. Within each zone, an in-depth analysis has taken place at a single reference city. The reference city research involves detailed data collection on 30–60 trees for each of the predominant 20 species. NYC is the reference city for the Northeast region. The concept is that any city or town within a particular zone can then feed their street tree inventory data into the model to produce a fairly accurate calculation of the aesthetic and environmental benefits of their tree stock without the associated cost of having their own individual analysis done by the US Forest Service (Kling, 2008).

In 2007, the US Forest Service's Center for Urban Forest Research produced a STRATUM report for NYC DPR's Commissioner Adrian Benepe (Peper *et al*., 2007). This STRATUM analysis calculated that the street tree population of NYC, identified in the 2005–2006 tree census, provided an estimated $121.9 million in annual benefits. This translates to $209 per tree. These benefits are broken down in Table 5 below:

Table 5 Annual benefits provided by New York City's street tree population as estimated by STRATUM (Peper *et al*., 2007).

| Annual benefits | Total value ($) | Value ($) per tree |
|---|---|---|
| Energy | $27 818 220 | $47.63 |
| Air quality | $5 269 572 | $9.02 |
| Stormwater catchment | $35 628 224 | $61.00 |
| Carbon dioxide reduction | $754 947 | $1.29 |
| Aesthetic/other | $52 492 384 | $89.88 |
| **Total** | **$121 963 347** | **$208.82** |

At the time of the report NYC DPR estimated that it spent $21.8 million annually on planting new trees and maintaining existing street trees (Peper *et al*., 2007). Therefore, the street tree population provides $100.2 million or $172 per tree in net annual benefits to the city. It can also therefore be deduced that for every $1 spent on tree care operations, the city receives $5.60 in benefits. Aside from these benefits, STRATUM also estimated the replacement costs of the NYC street tree population at $2.3 billion or $3938 per tree (Peper *et al*., 2007).

## Justifying greater resources through research

A greater appreciation of the value and functions of an urban forest can be used to justify increased support and resources for its correct management (McPhearson *et al*., 2010). In NYC the quantified figures for environmental benefits produced by UFORE and STRATUM have been invaluable and very influential. NYC DPR's Commissioner Benepe said of STRATUM, 'It was probably the single most important sales tool we used to convince policy makers to put money into trees' (McIntyre, 2008). Putting dollars figures on trees perhaps does not sit well with all parties, but, just as with proper tree valuation, it is essential. David Nowak said on this subject 'the monetizing (of trees) is a necessary evil. We know trees have great value but they're intrinsically underrated. You have to talk the language of the people who make decisions' (Jonnes, 2011). In essence the establishing of the benefits of an urban forest will become a vital, if not mandatory, duty of any manager trying to convince policy makers to invest in trees.

### Mayor Bloomberg invests in trees through PlaNYC

The knock-on effects of UFORE and STRATUM were dramatic in NYC. On Earth Day 2007, Major Bloomberg launched a comprehensive sustainable development plan for greener, greater NYC called PlaNYC (City of New York, 2007). PlaNYC lays out initiatives for the city to strive towards in five key dimensions of the urban environment. Trees play a significant role in 60% of those areas: namely land, water and air. The role of trees in this plan can be directly attributed to policy makers now understanding the vast potential that trees offer in combating many of the most worrying urban environmental challenges. UFORE data is actually quoted in PlaNYC as justification for the inclusion of trees in the initiatives. Furthermore, trees are relatively inexpensive, easy to access and return far more than is needed to be invested in them. Table 6 is a breakdown of the PlaNYC initiatives involving trees.

Table 6 PlaNYC initiatives involving trees (City of New York, 2007).

| Dimension of the environment | Initiative | Goal |
|---|---|---|
| **Land** | Fill every street tree opportunity in NYC to achieve 100% stocking | Plant 22 000 street trees annually to fill the estimated 220 000 open planting opportunities by 2017 |
| **Water** | Plant trees with improved pit designs | Maximize the ability of tree pits to capture stormwater |
| **Air** | Reforest 809 hectares of parkland | Complete reforestation project by 2017 |
| **Air** | Partner with stakeholders to help plant one million trees | Plant one million trees in the city on both private and public property by 2017 |

To achieve the PlaNYC initiatives involving trees, Mayor Bloomberg massively increased NYC DPR's annual urban forestry budget. $118 million was listed in the Capital budget (FY 2008–2017) for the 809 hectares of new forest and $247 million for the estimated 220 000 street trees needed to obtain 100% stocking level (City of New York, 2007). Prior to PlaNYC, NYC DPR was annually planting around 6000 trees; with PlaNYC, this figure sky-rocketed to 22 000 trees. It should be noted that the 220 000 street trees and those planted through the reforestation initiative will make up the majority of the city's 60% commitment to the million tree goal. The remaining 40% (400 000 trees) will be planted by private and community organizations and homeowners (MillionTreesNYC, 2007a, 2007b).

In conclusion, Mayor Bloomberg planned to invest $365 million alone in tree planting over a decade because science and research had shown they play such a key role in producing a healthier and more sustainable environment for New Yorkers.

## Using research to direct urban forestry programmes

In addition to research being used to justify and secure resources for trees, it also should play a vital role in determining how those resources are used, or else the potential benefits of those additional resources may be squandered or lost. Research can be used to help set up programmes and monitor the progress of these programmes once operational. It can also be used to give insight into the outcomes of certain management decisions. Overall, research should be used to establish achievable goals and to formulate the most effective and efficient urban forestry programmes to reach them. Urban foresters should endeavour to run research driven programmes to guarantee success.

The 2006 report by the US Forest Service and the University of Vermont's Spatial Analysis Laboratory on the present and possible urban tree canopy (UTC) in NYC was clearly a key reference for Mayor Bloomberg's staff when formulating realistic initiatives and goals for PlaNYC. As stated before, the research established that NYC's UTC could be increased from 24% to as high as 42% (Grove *et al*., 2006). The report identified numerous opportunities where this UTC increase could be realized based on land use type. For example, UTC on the Public Right of Way could be increased from 6% (4317 hectares) to 9% (6497 hectares). Therefore these figures reinforce the management decision in PlaNYC to plant an additional 220 000 street trees to reach a 100% stocking to take full advantage of this potential 3% UTC. In terms of other land uses, the report established that there was around 2000 hectares of car parks in NYC, approximately 1% of the NYC land area, and these were covered by 76 hectares of UTC. The report estimated that this land use had the potential to contain as much as 478 hectares of UTC, so this represented another significant opportunity to add around 402 hectares of UTC. PlaNYC included an initiative for changing planning regulations mandating perimeter landscaping and adjacent street tree planting for commercial and community run parking lots over 557 square metres (City of New York, 2007). In addition, for parking lots over 1115 square metres, a specific number of canopy trees would be required inside those lots in planting islands.

UFORE made recommendations relating directly to air quality because the study had shown that the urban forest was taking in 38 374 tonnes of carbon each year and also removing 1998 tonnes of pollutants (Nowak *et al*., 2007). The UFORE report for NYC included a tree planting index map that used census data and tree stocking data to identify areas of high population with low tree stocking densities. UFORE recommended that these areas should be prioritized for planting first. This management concept has been taken forward and evolved in PlaNYC. In PlaNYC it states that the planting of the 220 000 street trees by NYC DPR will prioritize neighborhoods with the lowest UTC levels and the highest air quality concerns (City of New York, 2007). In practice NYC DPR has identified six neighbourhoods with lower than average tree stocking but higher than average asthma rates among young people (MillionTreesNYC, 2007a, 2007b).

These geographical areas are called Trees for Public Health (TPH) neighbourhoods and they are being prioritized first for tree planting.

## In-house urban forestry research

NYC DPR also has a rich history of performing its own research and analysis. The tree census is a great example of a relatively simple research project using predominantly volunteers and in-house staff to produce a vast wealth of invaluable information about the street tree inventory. This information was not only used to run the STRATUM analysis but is also used on a regular basis to help guide urban forestry programming. A clear understanding of every aspect of a resource can only aid in its successful management.

### Young tree mortality study

Perhaps some of the most impressive research undertaken by NYC DPR is a young street tree mortality study using in-house staff and interns. This study randomly selected and surveyed 13 405 street trees that had been in the ground between three and nine years (Lu *et al*., 2010). The survey was completed in the summers of 2006 and 2007 and examined how biological, social and urban design factors affected young street tree mortality. The results showed that 74.3% of the trees surveyed were alive, with the rest either dead or missing. This percentage was raised to 82.7% for trees planted in one and two-family residential areas and dropped to 60.3% for trees in areas with heavy traffic. This number dropped even further to a 53.1% survival rate for trees located in central street medians. The research also highlighted some other very interesting data on the impacts of species, tree guards and the tree pit type on mortality rates. Alarmingly, the London plane tree had the lowest survival rate when compared to 19 other species, especially when STRATUM identified it as the most important tree in the urban forest in terms of environmental benefits delivered (Peper *et al*., 2007). Surprisingly, this study also concluded that tree pit size had little impact on survival rates and that the presence of animal waste was actually associated with a higher survival rate. This in-house research is obviously an invaluable resource in helping guide NYC DPR in reaching 100% stocking of live trees in its streets.

### September 2010 tornado

Another example of the use of in-house research is perhaps less obvious and occurred when a tornado passed through NYC on 16 September 2010. After any storm event, gaining situational awareness of the type and location of damage is vital. This information is usually not available until qualified staffers have completed comprehensive field inspections, which could take several days if not weeks. Within two hours after the tornado, NYC DPR had received around 1000 calls reporting storm damage and had incorporated this into their forestry management system, ForMS. Using the addresses of these calls, NYC DPR was able to produce an initial map of the areas in the city that had suffered the brunt of the tree damage. This allowed for NYC DPR to provide key situational awareness data to the Mayor's Office and also the city's Office of Emergency Management. Valid situational awareness is essential in tempering an appropriate response to a tornado both in terms of requesting help and also in activating emergency debris clearance contracts.

Eventually, just under 10 000 calls had been made to NYC DPR to report storm damage. NYC DPR used 15 years of previous storm data to explain to decision makers how severe this event was compared to previous storms and hurricanes. This provided the justification for a vast increase in the resources available for cleaning up the damage and for the help that was asked from other entities including the Federal Emergency Management Agency.

NYC DPR also used previous storm data to extrapolate from the confirmed number of uprooted trees how many of those had potentially caused sidewalk damaged when they fell. This data was then provided directly to the New York City Department of Design and Construction (NYC DDC) who were tasked with repairing these damaged sidewalks. This allowed DDC to start the process of bidding out emergency contracts without having to wait for all the field inspections to be completed.

Essentially, NYC DPR used research and analysis to give rapid situational awareness of the storm damage. This allowed for a far quicker gathering and deployment of appropriate resources needed to perform the clean-up operation and also communicating the severity of the damage to policy makers.

## Conclusions and future research

This paper has endeavoured to illustrate the vital role of research in shaping the NYC urban forest and the programs of NYC DPR. Urban forestry research has placed trees into the toolbox of urban planners battling to mitigate the negative impacts of city life and also take a responsible stance on the wider issue of climate change. Research should be an essential component of any urban forestry programme. Even in-house research of existing programmes can provide vital data and guidance for maximizing the benefits generated by those efforts. Research is a compass to guide urban forestry efforts as well as to help justify additional resources. NYC DPR has recently opened an urban field station in partnership with the US Forest Service at Fort Totten in Queens. This facility supports research by providing a fully equipped base for researchers to carry out their studies within NYC's urban forest. NYC DPR intends to use this resource to continually identify, pursue and undertake urban forestry research that assists the agency in its goal of providing the highest quality, hardest working and most sustainable urban forest to New Yorkers it possibly can.

## References


CITY OF NEW YORK (2007). *PlaNYC: A Greener, Greater, New York*. City of New York, Mayor Michael R. Bloomberg.

GROVE, J.M., O'NEIL-DUNNE, J., PELLETIER, K., NOWAK, D. AND WALTON, J. (2006). *A report on New York City's present and possible urban tree canopy*. Prepared for Fiona Watt, Chief of the Division of Forestry and Horticulture. New York City Department of Parks & Recreation, US Department of Agriculture Forest Service, Northern Research Station. [Online] Available at: http://nrs.fs.fed.us/nyc/localresources/downloads/Grove_UTC_NYC_FINAL.pdf [Accessed 15/01/11].

JONNES, J. (2011). What is a tree worth? *The Wilson Quarterly*, Winter 2011. [Online] Available at: http://www.wilsonquarterly.com/article.cfm?aid=1772 [Accessed 23/02/11].

KAPLAN, R. AND KAPLAN, S. (1989). *The Experience of Nature: A Psychological Perspective*. Cambridge University Press, New York.

KLING, J. (2008). Greener cities: US Forest Service software package helps cities manage their urban treescape. *Science Perspectives Fall 2008*. US Department of Agriculture Forest Service, Pacific Southwest Research Station.

KOU, F.E., BACAICOA, M. AND SULLIVAN, W.C. (1998). Transforming inner city landscapes: trees, sense of safety, and preference. *Environment and Behavior* **30**(1), 28–59.

LEWIS, C.A. (1996). *Green Nature/Human Nature: The Meaning of Plants in Our Lives*. University of Illinois Press, Chicago.

LU, J.W.T., SVENDSEN, E.S., CAMPBELL, L.K., GREENFELD, J., BRADEN, J., KING, K.L. AND FALXA-RAYMOND, N. (2010). Biological, social, and urban design factors affecting young street tree mortality in New York City. *Cities and the Environment* **3**(1), article 5. [Online] Available at: http://escholarship.bc.edu/cate/vol3/iss1/5 [Accessed 20/02/11].

MCINTYRE, L. (2008). Treeconomics. *Landscape Architecture*, February 2008. [Online] Available at: http://ccuh.ucdavis.edu/projects/qti/Treeconomics.pdf [Accessed 20/02/11].

MCPHEARSON, P.T., FELLER, M., FELSON, A., KARTY, R., LU, J.W.T., PALMER, M.I. AND WENSKUS, T. (2010). Assessing the Effects of the Urban Forest Restoration Effort of MillionTreesNYC on the Structure and Functioning of the New York City Ecosystems. *Cities and the Environment* **3**(1), article 7. [Online] Available at: http://escholarship.bc.edu/cate/vol3/iss1/7 [Accessed 20/02/11].

MCPHERSON, E.G., SIMPSON, J.R., PEPER, P.J., GARDNER, S.L., VARGAS, K.E. AND XIAO, Q. (2007). *Northeast Community Tree Guide: Benefits, Costs and Strategic Planting*. General Technical Report, PSW GTR-202. US Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.

MILLIONTREESNYC (2007A). *About a Million Trees*. MillionTreesNYC. [Online] Available at: http://www.milliontreesnyc.org/html/about/about.shtml [Accessed 30/01/11].

MILLIONTREESNYC (2007B). *Getting to a Million Trees, Target Neighborhoods*. MillionTreesNYC. [Online] Available at: http://www.milliontreesnyc.org/html/million_trees/neighborhoods.shtml [Accessed 30/01/11].

NEW YORK CITY DEPARTMENT OF PARKS & RECREATION (2007). *Tree Count!*. New York City Department of Parks & Recreation. [Online] Available at: http://www.nycgovparks.org/sub_your_park/trees_greenstreets/treescount/treecount_documents.php [Accessed 30/01/11].

NEW YORK CITY DEPARTMENT OF TRANSPORTATION (2008). *Sidewalks, the New York City Guide for Property Owners* [leaflet]. New York City Department of Transportation, Office of Sidewalk Management.

NOWAK, D.J., HOEHN, R., CRANE, D.E., STEVENS, J.C. AND WALTON, J.T. (2007).*Assessing urban forest effects and values: New York City's urban forest*. USDA Forest Service, Northern Resource Bulletin NRS-9. Newtown Square, Pennsylvania. 24 pp.

PEPER, P.J., MCPHERSON, E.G., SIMPSON, J.R., GARDNER, S.L., VARGAS, K.E. AND XIAO, Q. (2007). *New York City, New York, Municipal Forest Resource Analysis*. Technical Report to Adrian Benepe, Commissioner, Department of Parks & Recreation, New York City, New York. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station.

RAE, R.A., SIMON, G. AND BRADEN, J. (2010). Public reactions to new street tree planting. *Cities and the Environment* **3**(1), article 10. [Online] Available at: http://escholarship.bc.edu/cate/vol3/iss1/10 [Accessed 20/01/11].

ULRICH, R.S. (1984). View through a window may influence recovery from surgery. *Science* **224** (4647), 420–421.
US CENSUS BUREAU (2006). *State and County QuickFacts: New York City, New York*. US Census Bureau. [Online] Available at: http://quickfacts.census.gov/qfd/states/36/3651000.html [Accessed 15/01/11].
US FOREST SERVICE (2011). *i-Tree Urban Forest Assessment Applications*. US Department of Agriculture, Forest Service. [Online] Available at: http://www.itreetools.org/applications.php [Accessed 15/01/11].

# Measuring the ecosystem services of Torbay's trees: the Torbay i-Tree Eco pilot project


## Abstract

Trees are an integral part of urban ecosystems. They provide a myriad of services that benefit urban communities, such as offsetting carbon emissions, improving air quality by filtering pollutants and regulating local climate. These services improve the environmental quality of urban areas as well as human health and wellbeing.

This paper presents a quantitative valuation of a range of benefits delivered by Torbay's urban forest. Using collected field data, the i-Tree Eco model and existing scientific literature the value of Torbay's urban forest was estimated. Torbay has approximately 11.8% forest cover made up of around 818 000 trees at a density of 128 trees/ha; these trees represent an estimated structural asset worth over £280 million. In addition, Torbay's urban forest provides the equivalent of £345 811 in ecosystem services annually. An estimated 98 100 tonnes (approximately 15.4 tonnes/ha) of carbon is stored in Torbay's trees, with an additional gross carbon sequestration rate of 4279 tonnes carbon per year, every year (approximately 671 kg/ha/year). This equates to £1 474 508 in storage and £64 316 in annual sequestration. Contributions to improving the air quality of Torbay total over 50 tonnes of pollutants removed every year, which equates to an annual estimated value of £281 495.

This paper explains the current limitations of the model, where research scope and methods can be improved and which UK-specific data we were able to incorporate. It also presents a framework for applying the model in a wider UK context. The study demonstrates that i-Tree Eco can be meaningfully applied to the UK, and there is therefore the potential for similar studies in other urban areas.



**Keywords:**

benefit analysis, ecosystem services, urban forest



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## Introduction

Trees in the urban forest provide multiple ecosystem benefits (Nowak, 2006; Stenger *et al.*, 2009). Without measuring these ecosystem services no baseline can be established from which to monitor trends or to identify where additional resources are required. With increasing urbanisation there is a need to incorporate the role of the urban forest into long-term planning and climate adaptation strategies in order to improve environmental quality (Gill *et al.*, 2007).

Many studies have assessed the environmental value of an ecosystem qualitatively, listing the animals and plants found there and describing the network of systems – water, air, nutrients – that provide the underlying function. Some studies have also valued these services using contingent valuation (willingness to pay, willingness to accept), hedonic pricing, or avoided cost methods. Yet, to incorporate the role of the urban forest in environmental policies the impacts of trees need to be quantified. However, there have been few quantitative studies undertaken (Jim and Chen, 2009; de Groot *et al.*, 2010) and whilst there are systems that quantitatively measure the value of trees in the UK, none of these take an ecosystem services approach.

Since the release of the Millennium Ecosystem Assessment (2005a) there has been increased interest in defining and valuing our ecosystem services because, as a direct result of undervaluation, over two thirds of our natural ecosystems have been degraded (Millennium Ecosystem Assessment, 2005b). In order to develop viable strategies for conserving ecosystem services, it is important to estimate the monetary value so the importance can be demonstrated to the main stakeholders and beneficiaries (The Economics of Ecosystems and

Biodiversity, 2009). Furthermore, the ecological state of a city depends heavily on the state of its urban trees (Whitford *et al*., 2001; Dobbs *et al*., 2011) and to estimate the structure, function and value of the urban forest is an important first step in the sustainable management of natural capital.

## Study area

The study took place in the coastal borough of Torbay, comprising the towns of Torquay, Paignton and Brixham. The study area covers 63.75 km² centred at 50° 27′ N and 3° 33′ W and lies in the southwest of England. Torbay has a mild temperate climate due to its sheltered position and the effect of the Gulf Stream, with mean annual precipitation of 1000 mm and a mean average maximum and minimum temperature of 14°C and 7°C respectively (Met Office, 2010). The population is *circa* 134 000 (Torbay Council, 2010).

# Materials and methods

The basic process used by the i-Tree Eco model (also known as the Urban Forest Effects model or UFORE) is to calculate the correct number of survey plots needed to give a representative sample of an urban tree population. Survey data from these plots is used to calculate the species and age class structure, biomass and leaf area index (LAI) of the urban forest. This data is then combined with local climate and air pollution data to produce estimates of carbon sequestration and storage, air pollution interception and removal, the monetary value of these ecosystem services, and the structural value of the trees. The model can also estimate the predicted future benefits of the existing urban forest by applying growth rate calculations to the current stock.

## Field sampling

During the summer of 2010, 250 random 0.04 ha plots were distributed across the borough of Torbay. Plots were allocated using randomised grid sampling. The borough (study area) was divided into 250 equal grid cells with one plot randomly located within each grid cell. The study area was then sub-divided into smaller units of analysis (or strata) after the plots had been distributed (post-stratification). This approach better allows for future assessment to measure changes through time and space but at the cost of increased variance of the population estimates, because pre-stratification can focus more plots in areas of higher variability (Nowak *et al*., 2008a).

Out of the 250 plots, 241 were measured following field methods outlined in the i-Tree Eco user manual v 3.1. (i-Tree, 2010). Of the remaining 9 plots, 2 were inaccessible and 7 were located on private property, where permission to conduct the field measurements had been refused.

The 241 plots equate to 1 plot every 26.45 ha, which yields a relative standard error (of tree population) of ±11%. Details of how the number of plots influences the relative standard error over area are given in Nowak *et al.* (2008a). Other studies have frequently used 200, 0.04 ha plots yielding different variances (Nowak *et al*., 2008b). However, the number of plots chosen for this size study area has been determined to be sufficient to address the objectives of the project. By way of comparison the Chicago study used 745 plots equating to 1 plot every 80.2 ha, producing a standard error of ±10% (Nowak *et al*., 2010).

Following the protocol specified in the i-Tree Eco user manual v 3.1 (i-Tree, 2010), data was collected for each tree on every plot. Tree measurements included species, number of stems, diameter at breast height (dbh), total height, height to base of live crown, crown width, percentage crown die-back, crown light exposure and the position of the tree relative to the plot centre. Other information on the plot included percentage ground cover types, land use, percentage tree cover and plantable space. Shrub data (species and leaf volume) were also collected and their contribution included in the calculations for pollution removal – but not for carbon storage and sequestration. Full details of field data collection procedures are given in Nowak *et al*. (2008a).

## Analysis

We used i-Tree Eco to calculate and describe the structure of Torbay's urban forest, including species composition, tree density and condition, leaf area and biomass. This data was combined with additional data, including local climate and hourly pollution, and an estimated local leaf-on/leaf-off date. These variables were then analysed to quantify the ecosystem functions, including carbon sequestration and storage, air pollution removal and structural value. Full methodologies are included in Nowak and Crane (2000) and Nowak *et al*. (2008a).

We did not carry out any analysis of tree shading and evaporative cooling on building energy use and subsequent avoided carbon emissions. This component of the i-Tree Eco model is designed for US building types, energy use and emissions factors, limiting its use in international applications (i-Tree, 2010).

The model provides values in dollars. Pound values were first converted to dollars with the submitted data, and returned dollar values were converted back into pounds using the HM Revenue and Customs average for year spot rate to 31 March 2010 (£-$ = 1.517 and $-£ 0.659).

A number of UK-specific datasets were needed to run the model for the Torbay study area.

## Climate data

Weather data was obtained from the National Climatic Data Centre (2010), which although based in the USA provides datasets which are available for most major cities worldwide. This study used hourly climatic data from the Brixham weather station, which lies within the study area. Albedo (solar radiation) coefficients are also required. These do not vary much across the USA (Nowak *et al*., 2006) and 'best fit' values were used for Torbay based on the local climatic and geographical data supplied. Work is currently being undertaken in the USA to test how sensitive the model is to these coefficients in order to assess how accurate these values need to be; it is currently thought that they will not affect final figures very much (Nowak, personal communication, 8 February 2011).

## Pollution data

We obtained hourly pollution data from Defra (2010a). Archived pollution data is available online for pollution monitoring stations across the UK. Monitoring stations located in Torbay did not collect data on the complete set of pollutants required by the i-Tree Eco model, therefore proxy data was obtained from a monitoring station in Plymouth town centre for the years 1997 onwards. This proxy dataset was also incomplete due to the station being periodically inactive or out of service. Therefore data for the various pollutants over a five-year period (2005–2009) was obtained. This data was then spliced where there were gaps in order to provide a continuous hourly pollution dataset for $O_3$, $SO_2$, $NO_2$, $CO_2$, and $PM_{10}$ for one year.

## Leaf-on, leaf-off dates

Mean average leaf-on/leaf-off dates were calculated using datasets from the UK phenology records (Nature's Calendar, 2010). The data from eight species were selected to calculate an average (field maple (*Acer campestre*), sycamore (*Acer pseudoplatanus*), birch (*Betula pendula*), hawthorn (*Crataegus monogyna*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), sessile oak (*Quercus petraea*) and English oak (*Quercus robur*)) over a five-year period (2005–2009) from data collected across the UK, to provide a leaf-on date. However, because leaf-off is not in itself an event in the UK phenology database, a further average was taken from the 'first leaf fall' and 'bare tree' events for the eight species across the five years to provide an average date for the 'leaf-off' event. The average dates calculated for these events used in the study were; leaf-on, 19 April 2010 and leaf-off, 27 October 2010. As these are UK averages the estimate is likely to be conservative when applied to Torbay, which is widely understood to be subject to a milder microclimate.

## Structural data

For transplantable trees the United Kingdom and Ireland Regional Plant Appraisal Committee (UKI RPAC) – Guidance note: 1 (Hollis, 2007) was used with the average installed replacement cost (£500.00) and average transplantable size (30–35cm) of replacement trees in Torbay to determine a basic replacement price of £12.42/cm² (of cross sectional area of tree). These averages were calculated by obtaining the cost of supply of each replacement tree species and associated planting and maintenance costs to derive the installed replacement cost. Where no price existed for a given tree species then the 16–18cm class price from the UKI RPAC – Guidance note: 1 (Hollis, 2007) was used. This installed replacement unit cost is multiplied by trunk area and local species factor (0–1) to determine a tree's basic value.

Local species factors for the USA are determined by the Council of Tree and Landscape Appraisers (CLTA) regional groups and published by the International Society of Arboriculture. However, there is no published data for the UK. To undertake a full appraisal of local species factors would be a significant task (Hollis, 2007). Therefore, using the list of recorded tree species from the field study, knowledge of the locality and the species adaptability table (6.1) in Hibberd (1989), the growth characteristics, pest and disease susceptibility and environmental adaptability were determined to broadly gauge the local species factor into the following categories; low 0.33, medium 0.66 and high 1.

## Carbon storage and sequestration

The UFORE model quantifies composition and biomass for each tree using allometric equations from the literature. Where no equation can be found for an individual species, the average results from equations of the same genus are used. If no genus equations are found then the model uses average results from all broadleaf or conifer equations (Nowak, 1994; Nowak *et al*., 2008a).

Where equations estimate total above-ground tree wood biomass, the below-ground biomass was estimated using a root-to-shoot ratio of 0.26 (Nowak *et al*., 2008a). Where equations calculate fresh weight biomass, species or genus specific conversion factors were used to calculate the dry weight.

Urban trees tend to have less above-ground biomass than trees in forests. Therefore, biomass results for urban trees were adjusted accordingly by reducing biomass estimates by 20%, although no adjustment is made for trees in more natural stands (Nowak *et al*., 2008a). Estimates of annual carbon storage are calculated by converting tree dry-weight biomass by multiplying by 0.5 (Nowak *et al*., 2008a). Full methodologies are included in Nowak and Crane (2002) and Nowak *et al*. (2008a).

Gross carbon sequestration was estimated from average diameter growth per year for individual trees, land use types, diameter classes and dbh from field measurements (Nowak *et al*., 2008a). Adjusting for tree condition, gross carbon sequestration was calculated as the difference in the amount of carbon storage between a measured tree's actual and predicted carbon storage in one year.

Net carbon sequestration includes released carbon due to tree death and subsequent decomposition based on actual land use categories, mortality estimates, tree size and condition (Nowak *et al*., 2008a).

The model uses biomass formulas and standardised growth rates derived from US data and therefore our estimates for Torbay are sensitive to this. However, as the base growth rates used are from northern US areas (Nowak *et al*., 2008a), the growth and carbon sequestration rates are likely to be conservative when applied to Torbay.

Since population carbon estimates are based on individual trees, the model estimated the percentage of the measured tree that will die and decompose as opposed to a percentage of the tree population to die and decompose. These individual estimates were aggregated to estimate decomposition for the total population, based on field land use and two types of decomposition rates, rapid and delayed release (Nowak *et al*., 2008a). This assumes that urban trees release carbon soon after removal, whereas trees in forest or vacant areas are likely left standing for prolonged periods, thus delaying release (Escobedo *et al*., 2010); again, this is likely to result in a more conservative estimate of carbon stored. Additional methods and assumptions on standardised growth, decomposition rates and related carbon emissions are presented in Nowak and Crane (2002).

The value of the carbon stored and sequestered annually is a multiplication of the unit cost. The model uses the estimated marginal social cost of carbon dioxide based on a stochastic greenhouse damage model from a paper by Fankhauser (1994). This estimates a social cost of carbon in the order of \$20.00 per ton carbon for emissions between 1991 and 2000 rising to \$28.00 per ton carbon by 2021 (imperial). The value used in the study was calculated for 2010 at \$22.80 per tonne carbon (metric).

## Air pollution filtration

Air pollution removal is modelled within UFORE as a function of dry deposition and pollution concentration. Estimates of hourly pollution removal and its value are based on the local weather and solar radiation data, pollution data, leaf area index, leaf-on, leaf-off dates and geographical factors (Nowak *et al*., 2006).

Leaf area index (LAI) is calculated for trees and shrubs from the field data. The UFORE model estimates leaf area using regression equations (Nowak, 1994; Nowak and Crane, 2002; Nowak, Crane and Stevens, 2006) based on the input variables from the field data. Because trees can also emit volatile organic compounds (VOC's) – emissions that contribute to the formation of $O_3$ and CO – biogenic emissions from different tree species were accounted for in the calculations (Nowak *et al*., 2008a).

The value attributed to the pollution removal by trees is estimated within the model using the median externality values for the USA for each pollutant. These values are given in \$ per metric tonne as $O_3$ and $NO_2$ = \$9906 per metric tonne, CO = \$1407 per metric tonne, $PM_{10}$ = \$6614 per metric tonne and $SO_2$ = \$2425 per metric tonne (Nowak *et al*., 2008a). These values are considered as the estimated cost of pollution to society that is not accounted for in the market place of the goods or services that produced the pollution (Nowak *et al*., 2006).

## Structural value

The structural value is based on methods from the Council of Tree and Landscape Appraisers and is based on four variables: trunk area (cross sectional area at dbh), species, condition and location (local species factors). The field measurements (species, cross sectional area at dbh) are used to determine a basic value that is then multiplied by condition and local species factors to determine the final compensatory value (UFORE, 2010).

For trees larger than transplantable size the basic value (*BV*) was:

$$BV = RC+(BPx[TAa- TAr]x\ SF)$$

where *RC* is the replacement cost at its largest transplantable size, *BP* (basic price) is the local average cost per unit trunk area (£/cm²), *TAa* is the trunk area of the tree being appraised, *TAr* is the trunk area of the largest transplantable tree and *SF* is the local species factor.

For trees larger than 76.2 cm dbh, trunk area is adjusted downwards based on the assumption that a large mature tree will not increase in value as rapidly as its trunk area due to factors such as anticipated maintenance and structural safety (Council of Tree and Landscape Appraisers, 1992). The adjustment is:

$$ATA = -0.335d^2 + 176d - 7020$$

where *ATA* = adjusted trunk area, and *d* = the trunk diameter in inches.

Basic values for the trees were then multiplied by condition factors based on crown die-back and local species factors (UFORE, 2010). Data from all measured trees was used to determine the total compensatory value (structural value) of the tree population (Nowak *et al*., 2008a).

# Results and discussion

## Urban forest structure

There are approximately 818 000 trees in Torbay, situated on both private and public property. The results of the survey found that the private/public ownership split for the plots is 71.1% private, 28.9% public ownership. This is higher than the national average revealed in the results of *Trees in Towns II* (Britt and Johnston, 2008), where two-thirds of all trees and shrubs were found on private property (public ownership indicates that the land falls under the duty assigned to Torbay Borough Council to maintain at the public expense). Data for land ownership under these headings is not included within the parameters for i-Tree data collection. Instead, additional data was collected at the time of survey by way of assigning a percentage to each plot (rounded to the nearest 5%) for the area in private/public ownership.

The most common tree species found in Torbay are Leyland cypress (118 306 trees, 14.5%), ash (94 776 trees, 11.6%) and sycamore (81 703 trees, 10%). Total tree leaf area in Torbay is 51.7 km². (NB. whilst this is related to, it does not substitute for canopy cover.) The most dominant tree species in terms of total leaf area are ash (10.1 km², 19.5%), sycamore (8.5 km², 16.4%) and beech (3 km², 5.8%) (results are taken for trees only; results for shrubs are not included within these values).

The most important species (calculated as the sum of relative leaf area and relative composition) are those trees which have attained a larger stature and therefore larger stem diameters and total leaf areas (Table 1 shows the top ten trees by importance value). The top ten trees account for 67.6% of the total leaf area. While being the most numerous tree, Leyland cypress accounts for only 3.1% of the total leaf area. The dominance of ash as the climax community large canopy tree within Torbay's woodlands accounts for its status as the most important tree.

The recent *Trees in Towns II* survey (Britt and Johnston, 2008) used aerial photography to report mean average canopy cover for towns in England to be 8.2%. Mean canopy areas per plot were calculated at 11.1% for the South West and 11.8% for the South East. The Torbay study estimated tree canopy cover over the area of Torbay at 11.8% (a total of 752 ha). For comparison, canopy cover for Chicago and New York, USA, were estimated at 17% and 24% respectively (Rodbell and Marshall, 2009). Shrub cover for Torbay was 6.4%.

Table 1 Species importance within Torbay.

| Rank | Species | Percentage population | Percentage leaf area | Importance value |
|---|---|---|---|---|
| 1 | Ash | 11.6 | 19.5 | 31.1 |
| 2 | Sycamore | 10.0 | 16.4 | 26.4 |
| 3 | Leyland cypress | 14.5 | 3.1 | 17.5 |
| 4 | Hazel | 7.4 | 4.9 | 12.4 |
| 5 | Beech | 3.7 | 5.8 | 9.4 |
| 6 | Holm oak | 4.4 | 4.9 | 9.3 |
| 7 | Elm | 5.5 | 2.2 | 7.7 |
| 8 | Lawson cypress | 2.5 | 3.7 | 6.2 |
| 9 | Hawthorn | 5.4 | 0.8 | 6.2 |
| 10 | English oak | 2.2 | 3.7 | 6.0 |

Of trees in Torbay 57.1% are less than 15.2 cm diameter at breast height. This distribution (although normal) is skewed (Figure 1). Ideally one would expect a normal distribution with most trees in the middle diameter classes. However, it must be taken into account that because any stem over 2.5 cm diameter was included in the study, many small hedgerow trees were included within the analysis. This is especially relevant for one of the most commonly used amenity hedge species, Leyland cypress (with 65.8% of trees within the population at less than 15.2 cm stem diameter). Large numbers of hedgerow Leyland cypress trees were recorded with small stem-diameters and crown-volumes (due to their repeated clipping as hedges). Also, within woodland plots, many small trees in the understorey were also included.

In terms of continental origin, Table 2 shows percentages for each of the six continents from which the 102 species found in Torbay originate. By far the most dominant continent of origin is Europe. It is interesting to note that of the species of European origin, 51.4% are native to the UK, which represents 35.3% of all species found.

Table 2 Origin of species within Torbay.

| Origin | Percentage |
|---|---|
| Europe | 68.9 |
| N. America | 14.6 |
| Asia | 6.8 |
| Australasia | 5.8 |
| S. America | 2.9 |
| Africa | 1.0 |
| UK (as % of European species) | 51.4 |
| UK (as % of total species) | 35.3 |

The structural value of Torbay's trees amounts to £280 million. The CTLA value is a conservative value based on a tree in average condition, which will overestimate the value of some trees, and underestimate others. This approach serves to give a credible value for all the trees in Torbay. CTLA methodology does not apply a value to the trees as an amenity, and this is not considered here. The value of each tree applies to its replacement cost only, and is partially theoretical, as it is not possible to buy and transplant large trees in the event that they are lost. Through depreciating the values for the trees by species (i.e. suitability to the environment), condition (physiological and structural defects, life expectancy) and location (as trees contribute to the market value of property in an area, they can be assigned a proportion of this value; larger trees are effectively 'worth more'), a realistic value for trees is obtained, which realises the significance of the contribution of a tree to its environment. See Hollis (2009) for a thorough evaluation of the system.

## Climate change, carbon storage and sequestration

Climate change is now recognised as one of the most serious challenges facing us today (Wilby, 2007; Lindner *et al*., 2010) and its potential impacts for trees and forests are well documented (Freer-Smith *et al.*, 2007). The UK climate change scenarios (UKCIP, 2009) indicate average annual temperature increases of between 1 and 5°C by 2080. However, these scenarios do not take urban surfaces into account (Gill *et al*., 2007), which have the potential to further increase these predicted temperatures due to the urban heat island effect.

Urban trees help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue, by altering energy use in buildings, thereby altering carbon dioxide emissions from fossil fuel based power plants and also by protecting soils, one of the largest terrestrial sinks of carbon (Reichstein in Freer-Smith *et al*., 2007). They will also be useful in adapting to climate change through evaporative cooling of the urban environment (Gill *et al*., 2007; Escobedo *et al*., 2010).

The model estimated that Torbay's trees store 98 100 tonnes of carbon (15 tonnes of carbon per ha) and sequester a further 4279 tonnes per year (0.7 tonnes of carbon per ha). Net carbon sequestration is estimated at 3320 tonnes taking into account tree mortality. As trees die and decay they release much of the stored carbon back into the atmosphere. This is illustrated most significantly in the net amount for elm (Table 3), which despite a large population have a negative net sequestration rate due to their short lifespan; a consequence of Dutch elm disease.

Torbay's baseline (2005/6) total emissions were estimated at 750 000 tonnes of carbon (Torbay Council, 2008), over seven times more than the total carbon stored in the borough's urban forest and equating to 5.6 tonnes of carbon per capita. Based on these figures the urban forest can offset the emissions from 592 residents, which accounts for less than 0.5% of total emissions.

The direct impacts of trees on $CO_2$ seem at first glance to be negligible. However, the potential for the urban forest to reduce $CO_2$ emissions through energy reduction, and its role in climate adaptation, lowering urban temperatures through

Figure 1 Tree composition in Torbay by diameter class.

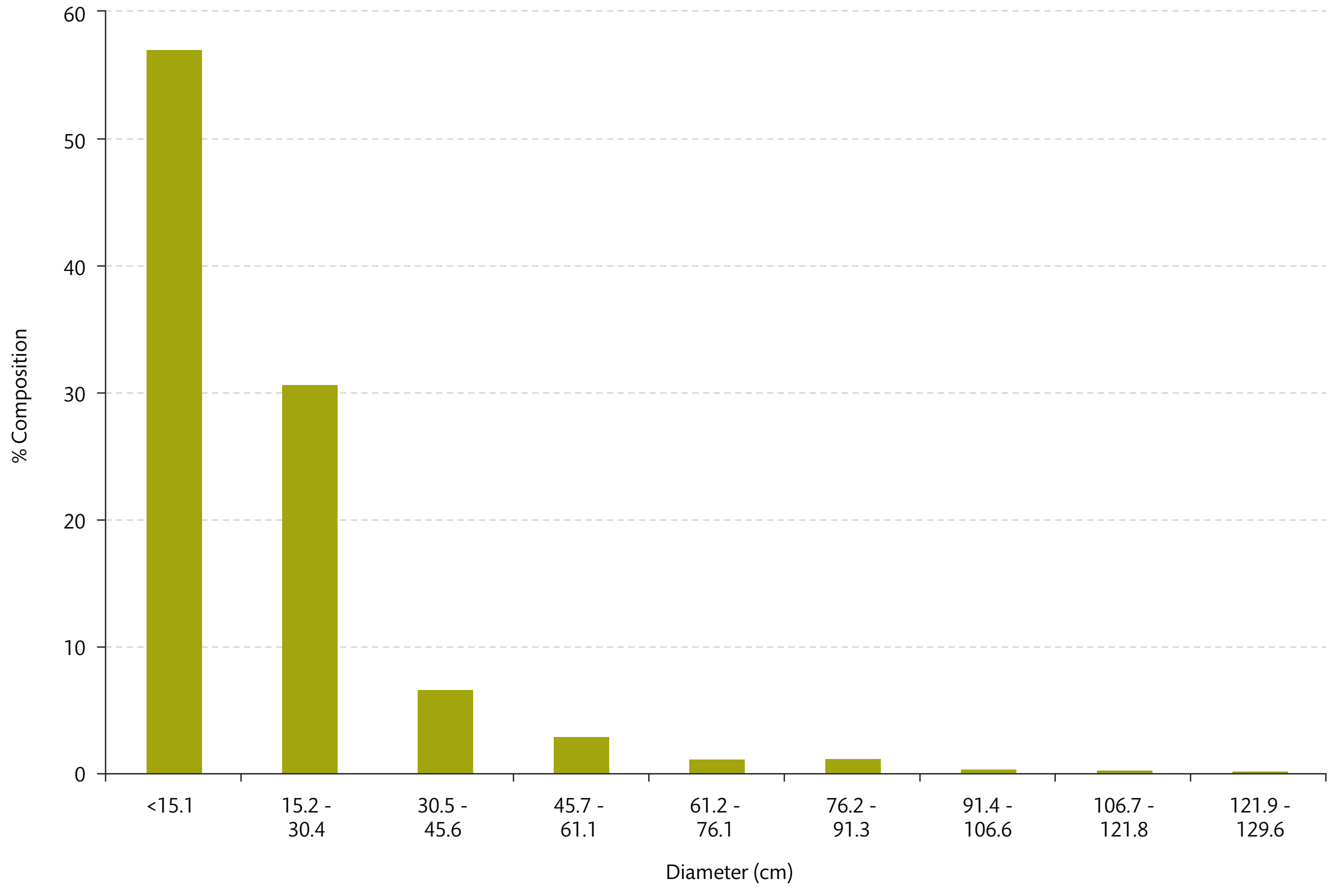



Table 3 Carbon storage and sequestration of the ten most significant trees in Torbay.

| Species | Number of trees | | Carbon (mt) | | Gross seq (mt/yr) | | Net seq (mt/yr) | | Leaf area (km²) | | Leaf biomass (mt) | | Carbon | Net seq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Val | SE | Val | SE | Val | SE | Val | SE | Val | SE | Val | SE | Value (£) | Value (£) |
| **Leyland cypress** | 118 306 | 35 361 | 2430.77 | 662.22 | 268.75 | 74.93 | 255.68 | 71.12 | 1.581 | 0.433 | 370.55 | 101.43 | 36 536 | 3843 |
| **Ash** | 94 776 | 32 088 | 11 399.19 | 3771.22 | 506.6 | 145.48 | 470.61 | 134.75 | 10.091 | 2.976 | 1 073.56 | 316.56 | 171 337 | 7074 |
| **Sycamore** | 81 703 | 23 197 | 18 142.32 | 7048.52 | 661.7 | 197.74 | 597.8 | 174.52 | 8.493 | 2.466 | 593.94 | 172.46 | 272 691 | 8985 |
| **Hazel** | 60 787 | 22 128 | 2344.55 | 963.41 | 186.59 | 67.86 | 160.9 | 64.64 | 2.549 | 0.899 | 177 | 62.41 | 35 240 | 2418 |
| **Elm** | 45 100 | 21 600 | 3466.27 | 1675.56 | 112.98 | 53.7 | -289.69 | 263.14 | 1.147 | 0.559 | 78.09 | 38.07 | 52 100 | -4354 |
| **Hawthorn** | 43 793 | 18 142 | 800.52 | 299.41 | 87.54 | 31.14 | 84.47 | 29.69 | 0.432 | 0.151 | 54.4 | 19.04 | 12 032 | 1270 |
| **Holm oak** | 35 949 | 12 999 | 9934.76 | 3845.19 | 425.14 | 160.98 | 291.65 | 158.86 | 2.54 | 0.974 | 233.13 | 89.34 | 149 326 | 4384 |
| **Beech** | 30 067 | 14 147 | 7385.11 | 3960.2 | 260.32 | 111.87 | 222.25 | 92.25 | 2.984 | 1.169 | 149.34 | 58.5 | 111 003 | 3341 |
| **Lawson cypress** | 20 262 | 5818 | 3945.47 | 2567.21 | 115.78 | 58.13 | 94.19 | 48.52 | 1.936 | 1.107 | 484.02 | 276.76 | 59 303 | 1416 |
| **English oak** | 18 302 | 7484 | 6713.92 | 3572.15 | 211.87 | 96.12 | 192.47 | 86.62 | 1.937 | 0.887 | 128.98 | 59.07 | 100 915 | 2893 |

evaporative cooling and protecting soil carbon, should not be overlooked. Although these particular ecosystem functions were not quantified as part of this study, Gill *et al.*, (2007) reported that increasing green cover by 10% within urban areas in Manchester could reduce surface temperatures by 2.2 to 2.5 °C.

Torbay has a large proportion of smaller (both in age and ultimate size potential) trees and carbon sequestration from small trees is minimal (Escobedo *et al.*, 2010). However a proportion of these trees will grow, thus offsetting the decomposition from tree mortality.

The estimates of carbon stored in the urban forest are likely to be conservative as soil carbon has not been factored into the evaluation. Furthermore, the urban forest can also reduce emissions indirectly, and if more trees able to achieve a larger size are planted, additional carbon can be stored in the urban forest. However, tree establishment and maintenance operations will offset some of these gains.

## Air pollution removal

Air pollution from transportation and industry is a major public health issue in urban areas (Beckett *et al*., 1998; Bolund and Hunhammar, 1999; Tiwary *et al.*, 2009). Urban trees can make significant contributions to improving urban air quality (Freer-Smith *et al.*, 2005) by removing air pollution through dry deposition, a mechanism by which gaseous and particulate pollutants are captured on plant surfaces and are either absorbed into the plant through the stomata (Jim and Chen, 2008), or introduced to the soil through leaf fall. Trees are capable of higher rates of dry deposition than other land types (McDonald *et al*., 2007) and also alter the urban atmosphere by reducing levels of ozone, because although some species can contribute to VOC emissions, the cooling effect of the urban forest on air temperature reduces ozone to greater effect (Nowak *et al*., 2000).

Torbay's trees remove 50 tons of pollutants every year with an estimated value of £281 000 (Figure 2). Pollution removal was greatest for ozone, $O_3$, followed by $PM_{10}$, $NO_2$ and $SO_2$. Recorded CO levels were negligible.

**Figure 2** Total pollution removed.

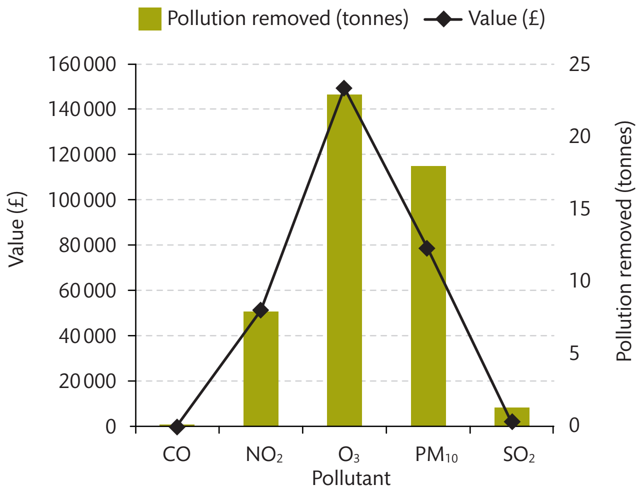
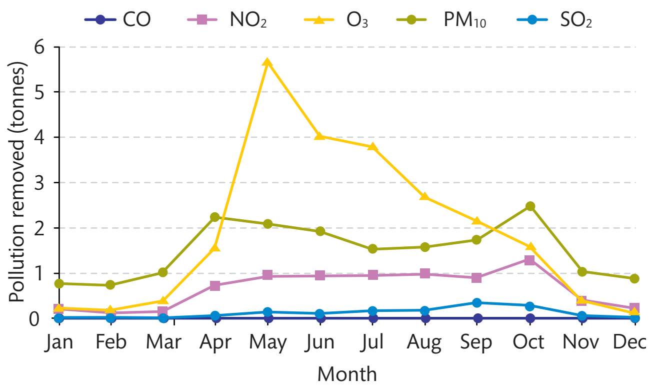



Figure 3 shows monthly removal, which varied, peaking in May for $O_3$ and in October for other pollutants. The monthly pattern of removal differed from observations in the USA in which peak removal rates tend to occur in the summer months (Nowak, 1994). These differences could be attributed to the poor summers of 2007–2009 from which the climatic and pollution datasets were taken, as one would typically expect pollution levels to build over the summer months, peaking at the end of the summer.

**Figure 3** Monthly pollution removal.




Total pollution removal in Torbay is 0.002 tonnes per ha per year. These values were lower than have been recorded by other studies; 0.009 tonnes per ha per year in Tiwary *et al.* (2009) for a site in London ($PM_{10}$ only) and 0.023 tonnes per ha per year in Jim and Chen (2008) for a site in Guangzhou, China. However, the greater pollution concentrations and canopy cover areas observed in these studies will result in more pollutants being removed. Greater tree cover, pollution concentrations and LAI are the main factors influencing pollution filtration and therefore increasing areas of tree planting has been shown to make further improvements to air quality (Escobedo and Nowak, 2009). Furthermore, because filtering capacity is closely linked to leaf area (Nowak, 1994) it is generally trees with larger canopy potential that provide the most benefits.

Available planting space in Torbay has been estimated from the study at 8%. McDonald *et al.* (2007) reported in a modelling study that by increasing tree cover by 13% in the West Midlands, $PM_{10}$ concentrations alone could be reduced by up to 10%. Species selection is an important consideration; for example, conifers are capable of capturing more particulates but are not considered to be as tolerant as broadleaves (Beckett *et al*., 1998). As different species can capture different sizes of particulate (Freer-Smith *et al*., 2005) a broad range of species should be considered for planting in any air quality strategy. Donovan (2003), quoted in McDonald *et al.* (2007), developed an Urban Air Tree Quality Score as a decision support tool for this purpose.

Uncertainties in the quantification have been acknowledged, such as the application of US externality values on the pollutants and the use of a local proxy site for pollution data. While the USA uses abatement cost values (based on what it would cost to clean the air by mechanical means), in the UK pollution values are based on damage costs, which were not suitable for local modelling without further work and did not cover all the pollutants monitored in the UK (Defra, 2010b). Furthermore, dry deposition rates were modelled based on generic values due to lack of empirical data and no account is made of wet deposition.

Tiwary *et al*. (2009) reported that although the UFORE method has limitations based on these inherent assumptions, a different methodology used by Broadmeadow *et al*. (1998) in the UK gave results that would suggest that the models being evaluated as part of that study were reasonably reliable.

# Conclusions

The UFORE model was originally developed using geographically specific US growth rates. Tree species in the UK have different growth rates, and therefore biomass and leaf area estimates, and the subsequent provision of ecosystem services will also differ. Applying i-Tree Eco to British conditions could result in the over or under estimation of the reported values. As the UFORE model has been applied in other non-US cities, it would be interesting to compare results. However, for the most accurate use of the model, the algorithms should be adapted to suit UK conditions.

The values presented in this study represent only a portion of the total value of the urban forest of Torbay because only a proportion of the total benefits have been evaluated. Trees confer many other benefits. Benefits such as avoided energy costs for cooling and heating, visual amenity, human health, tourism, ecological benefits, and other provisioning and regulating services such as timber and natural hazard mitigation (de Groot *et al.*, 2010) remain unquantified.

The importance of several of these benefits will increase as the predicted effects of climate change (such as increased summer droughts and winter rainfall) become more apparent. Under these scenarios, a healthy and diverse urban forest using appropriate species will be more resilient to change.

Although there is scope to improve the approach used in this study with UK-specific data, it still provides a useful indicator of the monetary value of urban trees, and allows for a better analysis of tree planting costs and benefits to be undertaken. The findings should also raise awareness of the wide range of ecosystem services delivered by trees in urban areas, strengthening the case for increasing urban greening, and promoting the sustainability of urban ecosystems.

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# References

BECKETT, K., FREER-SMITH, P. AND TAYLOR, G. (1998). Urban woodlands; their role in reducing the effects of particulate pollution. *Environmental Pollution*. **99**, 347–360.

BOLUND, P. AND HUNHAMMAR, S. (1999). Ecosystem services in urban areas. *Ecological Economic* **29**, 293–301.

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II – A new survey of urban trees in England and their condition and management*. Department for Communities and Local Government, London.

BROADMEADOW, M.S.J., BECKETT, P., JACKSON, S., FREER-SMITH, P.H. AND TAYLOR, G. (1998). *Trees and Pollution Abatement*. Forest Research Annual Report and Accounts 1997–1998. The Stationery Office, London.

COUNCIL OF TREE AND LANDSCAPE APPRAISERS (1992). *Guide for plant appraisal*. International Society of Arboriculture, Savoy, Illinois.

DEFRA (2010A). *Pre-formatted files of automatic monitoring data*. [Online] Available at: http://uk-air.defra.gov.uk/data/flat_filessite_id=PLYM&zone_id=11 [Accessed September 2010].

DEFRA (2010B). *Air quality damage costs*. [Online] Available at: http://www.defra.gov.uk/environment/quality/air/airquality/panels/igcb/guidance/index.htm [Accessed December 2010].

DE GROOT, R., ALKEMADE, R., BRAAT, L., HEIN, L. AND WILLEMEN, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity* **7**, 260–270.

DOBBS, C., ESCOBEDO, F. AND ZIPPERER, W. (2011). A framework for developing urban forest ecosystem services and goods indicators. *Landscape and Urban Planning* **99**(3-4), 196-206.

ESCOBEDO, F. AND NOWAK, D. (2009). Spatial heterogeneity and air pollution removal by an urban forest. *Landscape and Urban Planning* **90**, 102–110.

ESCOBEDO, F., VARELA, S., ZHAO, M., WAGNER, J. AND ZIPPERER, W. (2010). Analyzing the efficacy of subtropical urban forests in offsetting the carbon emissions from cities. *Environmental Science and Policy* **13**, 362–372.

FANKHAUSER, S. (1994). The social costs of greenhouse gas emissions: An expected value approach. *Energy Journal* **15**(2), 157–184.

FREER-SMITH, P., BECKETT, K. AND TAYLOR, G. (2005). Deposition velocities to *Sorbus aria*, *Acer campestre*, *Populus deltoides* x *trichocarpa 'beupre'*, *Pinus nigra* and *X Cupressocyparis leylandii* for coarse, fine and ultra fine particles in the urban environment. *Environmental Pollution* **133**, 157–167.

FREER-SMITH, P., BROADMEADOW, M. AND LYNCH, J. (EDS.) (2007). *Forestry and climate change*. CAB International, Trowbridge.

GILL, S., HANDLEY, A., ENNOS, A. AND PAULETT, S. (2007). Adapting cities for climate change: the role of green infrastructure. *Built Environment* **33**(1), 115–133.

HIBBERD, B. (1989). *Urban forestry practice*. Forestry Commission Handbook (FCHB005). HMSO, London.

HOLLIS, A. (2007). Depreciated replacement cost in amenity tree valuation. UKI-RPAC guidance note 1.

HOLLIS, A. (2009). A critical analysis of CTLA's depreciation factors – Do inherent inconsistencies of method complicate the simplicity of process? *Arboricultural Journal* **32**, 157–166.

I-TREE (2010). *i-Tree software suite v3.1* [Online] Available at: http://www.itreetools.org/resources/manuals.php [Accessed 12/01/11].

JIM, C.Y. AND CHEN, W. (2008). Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou (China). *Journal of Environmental Management* **88**, 665–676.

JIM, C.Y. AND CHEN, W. (2009). Ecosystem Services and valuation of urban forests in China. *Cities* **26**, 187–194.

LINDNER, M., MAROSCHEK, M., NETHERER, S., KREMER, A., BARBATI, A., GARCIA-GONZALO, J., SEIDL, R., DELZON, S., CORONA, P., KOLSTROM, M., LEXER, M. AND MARCHETTI, M. (2010). Climate change impacts, adaptive capacity and vulnerability of European forest ecosystems. *Forest Ecology and Management* **259**, 698–709.

MCDONALD, A., BEALEY, W., FOWLER, D., DRAGOSITS, U., SKIBA, U., SMITH, R., DONOVAN, R., BRETT, H., HEWITT, C. AND NEMITZ, E. (2007). Quantifying the effect of urban tree planting on concentrations and depositions of $PM_{10}$ in two urban conurbations. *Atmospheric Environment* **41**, 8455–8467.

MET OFFICE (2010). *Climate maps*. [Online] Available at: http://www.metoffice.gov.uk/climate/uk/averages/regmapavge.html#swengland [Accessed 01/02/11].

MILLENNIUM ECOSYSTEM ASSESSMENT (2005A). *Ecosystems and human wellbeing*. [Online] Available at: http://www.maweb.org/documents/document.356.aspx.pdf [Accessed 14/03/2010].

MILLENNIUM ECOSYSTEM ASSESSMENT (2005B). *Ecosystems and human well-being*. Summary for decision makers. Island Press, Washington D.C. [Online] Available at: http://www.millenniumassessment.org/documents/document.356.aspx.pdf [Accessed 23/07/10].

NATIONAL CLIMATIC DATA CENTRE (2010). *Brixham weather* [Online] Available at: http://gis.ncdc.noaa.gov/maps/ncs.map [Accessed 14/12/10].

NATURE'S CALENDAR (2010). *UK phenology records*. [Online] Available at: http://www.naturescalendar.org.uk [Accessed 16/09/10].

NOWAK, D. (1994). Atmospheric carbon dioxide reduction by Chicago's urban forest. *In*: McPherson, E., Nowak, D. and Rowntree, R., (eds). *Chicago's urban forest ecosystem: Results of the Chicago Urban Forest Climate Project*. USDA Forest Service, Radnor, Pennsylvania.

NOWAK, D. (2006). Institutionalizing urban forestry as a 'biotechnology' to improve environmental quality. *Urban Forestry and Urban Greening*, **5**, 93–100.

NOWAK, D., CIVEROLO, K., RAO, S., SISTLA, G., LULEY, C. AND CRANE, D. (2000). A modeling study of the impact of urban trees on ozone. *Atmospheric Environment* **34**, 1601–1613.

NOWAK, D. AND CRANE, D. (2000). The urban forest effects model: quantifying urban forest structure and functions. *In*: Hansen, M. and Burk, T. (eds.) *Integrated Tools for Natural Resources in the 21st Century, Proceedings of the IUFRO conference*. Boise, Idaho, USA, 16–20 August.

NOWAK, D. AND CRANE, D. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution* **116**, 381–389.

NOWAK, D., CRANE, D. AND STEVENS, J. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening* **4**, 115–123.

NOWAK, D., CRANE, D., STEVENS, J., HOEHN, R., WALTON, J. AND BOND, J. (2008A). A ground-based method of assessing urban forest structure and ecosystem services. *Arboriculture and Urban Forestry* **34**, 347–358.

NOWAK, D., HOEHN, R., CRANE, D., STEVENS, J. AND LEBLANC, F. (2010). *Assessing urban forest effects and values, Chicago's urban forest*. Resource bulletin NRS-37. USDA Forest Service, Radnor, Pennsylvania.
NOWAK, D., WALTON, J., STEVENS, J., CRANE, D. AND HOEHN, R. (2008B). Effect of plot and sample size on timing and precision of urban forest assessments. *Arboriculture and Urban Forestry* **34**(6), 386–390.
RODBELL, P. AND MARSHALL, S. (2009). Urban tree canopy as a contributor to community resilience. *In: Proceedings of the XIII World Forestry Congress*, Buenos Aires, Argentina.
STENGER, A., HAROU, P. AND NAVRUD, S. (2009). Valuing environmental goods and services derived from forests. *Journal of Forest Economics* **15**, 1–14.
THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY – D1 (2009). *The Economics of Ecosystems and Biodiversity Report for Policy Makers – Executive Summary*. Progress Press, Malta.
TIWARY, A., SINNET, D., PEACHEY, C., CHALABI, Z., VARDOULAKIS, S., FLETCHER, T., LEONARDI, G., GRUNDY, C., AZAPAGIC, A. AND HUTCHINGS, T. (2009). An integrated tool to assess the role of new planting in $PM_{10}$ capture and the human health benefits: A case study in London. *Environmental Pollution* **157**, 2645–2653.
TORBAY COUNCIL (2008). *A climate change strategy for Torbay 2008–2013*. [Online] Available at: http://www.torbay.gov.uk/climatechange [Accessed 20/09/10].
TORBAY COUNCIL (2010). *Torbay Statistics* [Online] Available at: http://www.torbay.gov.uk/factsfigures [Accessed 02/02/11].
UFORE (2010). *Methods* [Online] Available at: http://www.ufore.org/methods.html [Accessed 22/02/11].
UKCIP (2009). *Climate Change Scenarios*. [Online] Available at: http://www.ukcip.org.uk/ukcp09/ [Accessed 24/02/11].
WHILBY, R. (2007). A review of climate change impacts on the built environment. *Built Environment* **33**(1), 31–45.
WHITFORD, V., ENNOS, A. AND HANDLEY, J. (2001). City form and natural processes: indicators for the ecological performance of urban areas and their application to Merseyside, UK. *Landscape and Urban Planning* **20**(2), 91–103.

# A framework for strategic urban forest management planning and monitoring


## Abstract

With global climate change, ever-increasing urban populations and rapidly spreading invasive species and pests, the challenges facing urban forests today are immense. To address these challenges and achieve true sustainability, urban forest management programmes need to transition from a reactive maintenance approach to one of proactive management. The clear solution is collaborative, long-term, strategic urban forest management planning. This paper outlines a three-tiered planning framework comprising a high-level, 20-year strategic plan, with four five-year management plans, and 20 annual operating plans. The concept of active adaptive management is firmly embedded in this framework, providing managers with the opportunity to review the successes and shortcomings of their management activities on a systematic basis, and integrate new approaches or address new issues as required. The framework is further supported by a comprehensive set of criteria and indicators for performance assessment. These 25 criteria and indicators support the process of adaptive management by providing clear and consistent measures by which progress can be gauged, and are positioned as tools for improving the development and implementation of urban forest management plans over time. Finally, the flexibility of the framework and its applicability at different scales is highlighted with several case studies, including the development of strategic urban forest management plans for municipalities and golf courses.


## Introduction

The benefits provided by healthy and well-managed urban forests are far-reaching and extensively documented (e.g. Dwyer *et al.*, 1992; McPherson, 1994; Simpson, 1998; Kuo, 2003; Wolf, 2004; Donovan and Butry, 2010). There are, however, many challenges currently facing trees in urban and peri-urban areas. Generous estimates suggest that the average lifespan of a typical urban tree is 32 years and that many newly planted trees do not survive their first year (Moll and Ebenreck, 1989). A number of factors contribute to such dismally short lifespans and, as a result, few urban trees are ever able to reach their full genetic potential to provide important social, economic and environmental services for urban residents.

Cities and their surrounding areas are complex and dynamic entities. A wide range of decision makers, stakeholders and interest groups are active in setting the agenda in most communities, and urban forest managers must compete with other interests for limited resources. In spite of the additional challenges posed by invasive species, development intensification, climate change and other stress factors, a solution to effective urban forestry in this context lies in good planning that balances the need for immediate action with the need for a long-term vision. Effective planning can support the development and implementation of proactive, as opposed to reactive, management approaches in a strategic and collaborative fashion. Proactive management leads to tangible results in the form of increased operational efficiency, risk reduction, increased urban forest canopy and leaf area, and, perhaps most importantly, the sustained provision of ecological, social and economic benefits to urban residents and the greater environment.

The first part of this paper outlines the context for urban forest management planning and presents an effective 20-year planning framework for use in the development of urban forestry strategies. The second part builds upon the work of Clark *et al.* (1997) and demonstrates how a comprehensive and practical set of monitoring criteria and indicators tailored to assess urban forest sustainability can improve management planning and


**Keywords:**

adaptive management, canopy cover, criteria and indicators, municipal planning, relative canopy cover, sustainability, urban forestry



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implementation. Finally, the paper explores how these tools have been applied in southern Ontario, Canada, to work towards achieving true urban forest sustainability in communities of various sizes.

## The context for urban forest management today

The challenges to growing and maintaining healthy urban forests are numerous and, by necessity, must be addressed on a long-term horizon. Urban foresters must remember that they work on 'tree time'. Trees are a long-term investment, and successes and failures are rarely realised overnight because trees can take years to respond to stress factors or improvements designed to promote their health and longevity.

From a basic biological perspective, cities are difficult places to grow trees. Unlike in forests (where we all too often forget that trees come from), urban soils are typically of poor quality, limited in volume, and can be effectively sterile or even contaminated. Often heavily modified, urban tree rooting environments are typified by low biological activity, poor nutrient availability, compacted pore space and a number of other problems (Urban, 2008). Simply put, good soil is in short supply. Furthermore, trees must compete for space with various forms of built infrastructure, such as roads, buildings and sewers. In many jurisdictions, these grey infrastructure components take precedence over trees and other forms of green infrastructure, which are seen as additional niceties to be included in urban designs where feasible and when budgets permit.

Compounding the difficulties associated with poor-quality growing sites and inadequate soils is the reality of urban intensification and development. In 2011, the world population is expected to exceed seven billion, with over half now residing in towns and cities (UNFPA, 2010). This influx of urban citizens places increasing stresses on existing trees and makes urban land a premium commodity. In many areas, planning regulations require intensification in urban centres and settlement areas in an attempt to curb urban sprawl. Paradoxically, this leaves little room for trees in the very places where they are most beneficial.

Finally, the additional stress factors presented by climate change will continue to affect urban forests (2degreesC, 2007; Colombo, 2008; Galatowitsch *et al*., 2009). In highly urbanised communities, climate change-related events such as periods of extended drought, extreme winds, high temperatures and shifting species distribution patterns for both native and invasive species will further strain already thin operating budgets.

The challenges outlined above, including poor urban soils, intensification and climate change, are just three of many factors weighing against urban forest sustainability. Others include invasive species, pests and pathogens, limited knowledge of proper tree care practices, poor public perception of trees, and inadequate maintenance and management practices, among others. No matter what the threat, it is clear that attention needs to be given to planning for the future health and enhancement of the urban forest resource in any community, as was previously noted by van Wassenaer *et al*. (2000).

Any efforts to proactively manage urban forests to provide the greatest amount of benefits requires a targeted, strategic approach that is collaborative in nature and considers the wide range of stakeholders with interests in urban forest sustainability. Providing a framework for such a planning approach is one of the central objectives of this paper.

## A strategic framework for urban forest management planning

While the pace of daily life in urban areas is often accelerated, trees in cities can be relatively slow to respond to physical damage and environmental changes, whether they are negative or positive. Similarly, municipal governments are rarely, if ever, able to quickly summon the financial and human resources necessary to make meaningful changes to urban forest operations and management. As a result, a long-term planning horizon is needed in order to outline required action items, prioritize implementation and accommodate long-term budget planning. Even with the best laid plans, unexpected occurrences such as long-term droughts, invasive pests, or worsening economic circumstances may force significant reprioritisation of short- and medium-term operations. Planning on a longer time horizon can ensure that strategic objectives are still met.

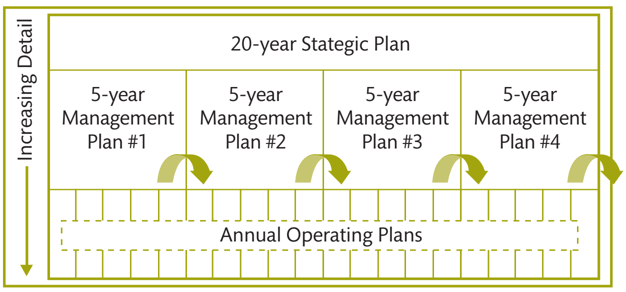
### Planning horizon and temporal framework

A number of municipalities in southern Ontario, Canada, have determined that a 20-year horizon is appropriate for planning a sustainable and healthy urban forest, and have developed plans using this framework. This timeframe enables short- and medium-term financial and organisational planning, while maintaining an established overall strategic direction that will remain unchanged and thus enable the community's vision for its urban forest to become realised.

While a long-term planning horizon is necessary to achieve urban forest sustainability, shorter-term objectives and day-to-day operations must be supported by more readily implementable directives. Therefore, an effective urban forest management plan must make clear links between long-term strategic directives, medium-term priorities, and day-to-day operational activities such as tree pruning or establishment.

This can be achieved through a three-tiered temporal framework (Figure 1) for urban forest management planning, wherein a 20-year strategic plan is divided into four five-year management plans, which are further subdivided into annual operating plans.

Figure 1 Temporal framework for a strategic urban forest management plan.




The highest level of the urban forest management plan sets out the vision, goals and objectives to be achieved by the end of the planning horizon. This 20-year strategic plan can be developed as a separate document from lower-level plans, and should provide connectivity to other relevant strategic documents and policies in the community. A vision, strategic objectives and guiding principles should be developed in consultation with municipal staff, community members and other stakeholders such as local land developers, environmental groups and organisations, and representatives of other levels of government (e.g. regional councils). These goals and vision should guide the overall direction of plan development, and must therefore be developed early on in the process.

Effective urban forest management requires an end goal – a reason to justify the expense and complexity associated with the undertaking. While every community will develop its own vision for what its urban forest should look like and what benefits its residents will enjoy, a workable guiding objective is presented below, stating that the goal of any community's urban forestry programme should be:

*To optimise the leaf area of the entire urban forest by establishing and maintaining a canopy of genetically appropriate (adapted and diverse) trees (and shrubs) with minimum risk to the public, and in a cost effective manner.*

Nested within the 20-year strategic plan are four five-year management plans. Each of these will be the first level of operational planning and represents the link between high-level strategic objectives and on-the-ground management activities. This level of planning also presents the opportunity to implement active adaptive management, defined by the Millennium Ecosystem Assessment project (2005) as:

*A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for the purpose of learning.*

This concept recognises that urban forests are complex, dynamic entities and that while managers may not always be able to predict changes they must be prepared to accommodate such changes while still working towards broader goals for the management of the resources in their care. Through active adaptive management, a problem is first carefully assessed and a strategy or approach is designed and implemented to address it. The results of the approach are then monitored in a systematic manner and any adjustments are made based on the experience gained and new information that has become available. The adjusted approach is implemented and the evaluation cycle continues for as long as is necessary to accomplish the goals or to accommodate changing environmental, social, or policy directions. This is achieved through the review of each five-year management plan near the end of its planning horizon, and subsequent five-year management plans are based upon the results of these reviews. Therefore, the intention is not to attempt to develop all four plans at once, but to develop them sequentially in response to lessons learned and, if applicable, changing priorities. This is represented graphically by the arrows connecting each five-year management plan shown in Figure 1.

The final level of planning is the annual operating plan, which directs day-to-day operations and can be used to project budget requirements for all aspects of maintaining the urban forest. Each annual plan may include detailed plans for tree establishment, pruning, removals, inspections and maintenance of the tree inventory. Such activities should be guided by directions outlined in the strategic and five-year plans. Initially, annual operating plans will need to address priorities derived from a community's tree inventory, but, as these are addressed over time, more effort can be focused on proactive management objectives. Annual operating plans can be integrated with a community's asset management system and GIS information technology to optimise resource allocation. For example, planting locations can be mapped on a municipal GIS to inform all related staff about the future location of street or park trees to help plan future maintenance activities.

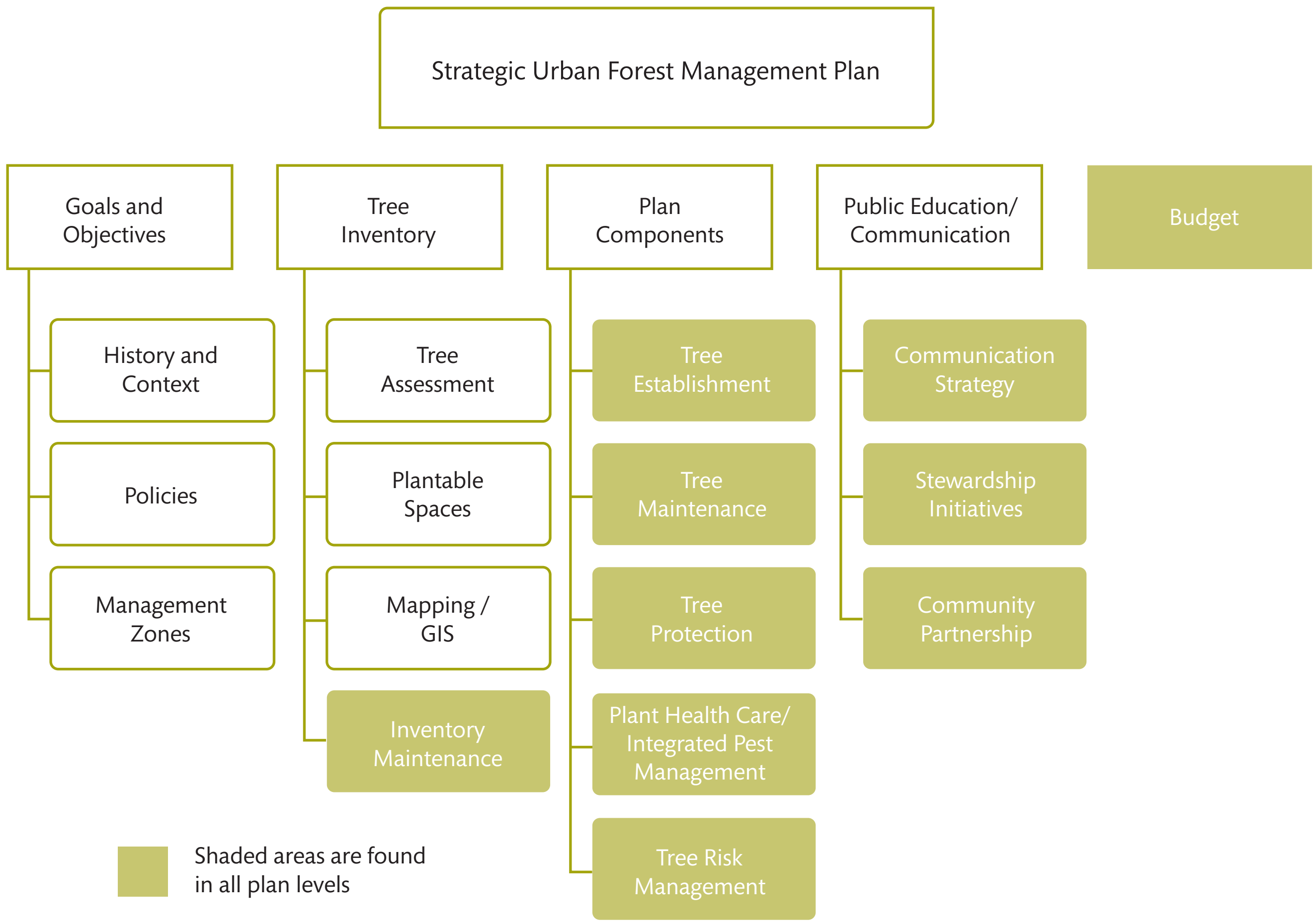
## Key urban forest management elements

Several key themes and issues should be addressed as components of any urban forest management plan, and some must be addressed at all three (20-year, five-year and annual) planning levels. The content and scope of each plan component can vary depending on a variety of factors specific to the community undertaking the planning process. These factors may include the community's urban forest objectives; its historical, current and anticipated land use cover; the degree to which it has already begun to undertake urban forest management; available resources; the level of stakeholder and community interest; and the willingness of the community and its residents to invest in the local urban forest.

Figure 2, below, represents the basic structure of a typical urban forest management plan developed using the framework outlined in this paper. The top row (the overall plan) is divided into five key components, which are further subdivided into different topic areas, or planning components. As stated, these will vary and should be tailored to each municipal context.

As noted above, some of these components (shaded in Figure 2) are addressed at each planning level. To illustrate how these components can be addressed at each level, let us consider the example of tree establishment. On a long-term horizon (20-year strategic plan), the plan can set long-term objectives such as increasing species diversity, developing improved tree planting standards, or increasing tree canopy cover through tree planting. At the medium-term (five-year management plan) level, the plan can commit to implementing pilot projects to test new tree

**Figure 2** Typical components of a strategic urban forest management plan.



species or planting methods, or might identify particular locations for targeted planting to provide specific benefits (e.g. more trees in urban heat island areas). At the annual operating plan level, operations staff might prepare planting lists and locations for next year's plantings to ensure adequate budget and staff allocations that address the mid and long-term objectives.

Conversely, other components (not shaded in Figure 2) may or may not need to be addressed at each planning level. For example, there may not be a need to plan for coordination with higher level management policies during day-to-day operations, and these would therefore not be considered in the development of an annual operating plan.

In order to effectively develop and support recommendations designed to improve urban forest management, each plan component must contain four elements to inform the recommendations. The first element is a review of current management practices and policies in the community, with regard for the particular subject area in question. The second is a review of relevant 'best management practices' from scientific and technical literature and precedents from other jurisdictions. The third component should compare the current status to best practices, and identify gaps and opportunities for improvement. Finally, the fourth component should review and consider input and ideas from the various internal and external stakeholders, typically garnered through a multi-part consultative process. This information provides the background and rationale for recommendations and resource requirements proposed in the management plan.

The key sections of a typical urban forest management plan are outlined in more detail, below.

## Urban forest/tree inventory

As is the case with any renewable resource, an inventory is an essential tool for the development of management strategies. It will identify details of the structure of the urban forest, which are necessary for the planning of management activities to achieve specific goals. These details may include species composition, the mixture of native and non-native species, age structure, tree condition, location, size, management history and habitat. Inventories may also reveal other valuable assets such as the presence of rare or endangered species that may otherwise be overlooked. A wide range of inventory options are available, from basic street tree assessments to broader urban forest resource analysis studies (e.g. i-Tree Eco), which can provide a better understanding of urban forest structure and function in both the public and private realm. The type of inventory used may also vary depending upon the extent of urban forest management in a given area. For example, intensively managed zones such as streets may have a higher level of inventory detail (e.g. individual tree assessment) than extensively managed zones such as natural areas (e.g. forest stand inventory or ecological classification).

Communities with well-developed inventories may develop much of the management direction based upon the results of such studies in this section of the plan. Communities with limited or no inventories may direct the plan towards collecting such data in order to inform future management. A key component of the tree inventory section should also be an inventory maintenance plan, outlining how the inventory will be updated and used to its fullest capacity on an ongoing basis.

## Tree establishment

At the level of the strategic plan, tree-planting priorities should reflect overall objectives with respect to tree cover, species distribution, tree replacement policies, stock specifications, habitat requirements and other considerations. At the management plan level, planting plans can be drawn up once an accurate assessment of the plantable spots is determined from the inventory or from other means of spatial analysis. Innovative approaches to providing suitable tree habitat should also be identified and recommendations to implement them should be developed.

## Tree maintenance

At the level of the strategic plan, the plan should establish overall goals for tree maintenance such as pruning, and define the minimum standards to be applied. Objectives to enable a transition from reactive to proactive management, including grid pruning, regular inspection, etc., should be developed. In the medium-term management plan, the plan should identify the areas in which tree maintenance will take place over the five-year term.

## Tree protection

This section should review current practices and threats related to tree protection and the municipal development approval process (if applicable) with respect to trees and tree protection. This section may also discuss existing, proposed or potential tree protection by-laws as well as tree-related guidelines for protection during the construction process.

## Plant health care and integrated pest management

The urban environment is hostile to the long-term health of trees and shrubs. Environmental stresses both above and below ground weaken natural defence systems and leave plants prone to insect infestations and diseases. Plant Health Care (PHC) and Integrated Pest Management (IPM) planning should be an integral part of any strategic plan. PHC is a proactive approach to tree management that strives to increase the health and vigour of trees such that their natural defence mechanisms will protect them. IPM includes similar aspects, with a focus on reducing pesticide use and managing and monitoring pest populations. Some aspects of PHC and IPM are:

- Proper tree selection: the right tree in the right place;
- Early pruning of young trees to establish strong structure for long-term stability;
- Fertilisation and watering according to the soil conditions and the species requirements;
- Structural support systems;
- Utilising an array of cultural practices and biological controls to reduce the use of fungicides, pesticides and herbicides;
- Pest vulnerability analysis;
- Regular monitoring and reporting;
- Active adaptive management.

## Tree risk management

Liability is a major concern for urban forest managers. At the strategic level, the plan should commit to developing a tree risk management strategy if one is not already in place, tailored to available resources and tolerance for risk. At the five-year management plan and annual operating levels, the plan should identify risk trees and outline implementation of mitigation practices.

## Outreach and public engagement

Effective communication is a vital part of urban forest management. In most jurisdictions, the urban forest is an 'unknown' entity that both the public and administrators take for granted rather than recognise as an important municipal and community asset. In many communities most of the urban forest is privately owned. Therefore, an educational communications and outreach programme for the community should be developed and implemented in order for urban forest management to be effective. This component should also outline existing and potential partnerships and funding sources.

## Budget

At the strategic level, items that must be considered in management and operational plans will be ascertained. The initial budget available to the urban forest management process will help to focus or prioritise the issues that can be addressed. Sources of funding, as well as opportunities for resource sharing, should also be identified. It is important to note that while recommendations should be realistic from a budgetary standpoint, current available resources should not limit or guide the direction of the plan, or prevent the development of progressive initiatives and recommendations.

## Monitoring

This section of the plan should include mechanisms for monitoring the implementation of the plan's recommendations and assessing successes and shortcomings. It is recommended that a criteria and indicators based approach to monitoring, as outlined in the following section of this paper, be used at the end of every management plan (i.e. five-year) cycle. This section should also include the baseline criteria and indicators-based analysis to provide a benchmark of the state of the urban forest prior to the development and implementation of the plan.

## Recommendations

In keeping with the proposed plan framework, it is suggested that recommendations to be implemented within the first five years be supported with accurate budget forecasts, clear priority rankings, delineation of responsibilities, and other supporting information such as potential partnerships, funding sources, etc. Recommendations for implementation in the remaining years of the strategic horizon can be supported by a priority ranking or a time range (e.g. 2015–2019), or can be slotted into one of the future five-year management plans (e.g. within 3rd planning cycle).

# Integrating criteria and indicators into strategic planning

A progressive urban forest management plan should include recommendations that improve the effectiveness and efficiency of a community's urban forestry programme, moving it from reactive maintenance to proactive management. However, the concept of active adaptive management embedded in such a plan necessitates regular monitoring to ensure that progress is being made towards urban forest sustainability. A means of defining sustainability is also required. For these reasons, the framework of criteria and indicators of urban forest sustainability, developed by Clark *et al*. (1997) and refined and updated by Kenney *et al*. (2011), is well suited for integration into the development and implementation of an urban forest management plan for any community.

The publications referenced above have discussed criteria and indicators in detail, and they will not be greatly expanded upon in this paper. In summary, this approach to planning includes 25 distinct criteria under three general topics (Vegetation Resource, Community Framework and Resource Management Approach). A community's current standing relative to each criterion is assessed by means of four indicators, ranging from low through moderate, good or optimal. Each indicator refers to a key objective; moving along the scale from low to optimal for each criterion places the community closer to achieving a sustainable urban forest. Table 1 shows three example criteria and their related indicators and key objectives.

A major strength of the criteria and indicators approach is that it enables an in-depth and comprehensive assessment of the current status and progress of an urban forest management programme. It also challenges the all-too-prevalent notion that overly simplistic metrics such as canopy cover percentage or the number of trees planted per year are, in and of themselves, good indicators of urban forest sustainability. Moreover, a criteria and indicators assessment illustrates the strengths of a community's urban forest management programme and, more importantly, clearly highlights opportunities for improvement. This in turn enables managers to more effectively allocate limited resources with the objective of moving towards optimal performance levels and sustainability.

Criteria and indicators are most useful at two stages of the management planning process. Firstly, they can be used to undertake a baseline assessment of the current status of a community's urban forest and forestry operations. Secondly, they are an invaluable tool for tracking the successes and shortcomings of each of the five-year management plans discussed in the previous section, in order to inform goal setting and prioritisation for each subsequent planning horizon.

As a method for undertaking a baseline assessment, criteria and indicators are typically reviewed at the outset of the management planning process by a community's head urban forester, or preferably by an inter-departmental committee including staff such as engineers, planners, communications personnel and information technologists. Outside the municipal realm, criteria and indicators can be reviewed by the various stakeholders who are in a position to inform and improve the indicators. Completing the level of assessment required to determine the appropriate indicator for each criterion may take some time and effort, but is an effective way to set the priorities for the strategic management plan. Once the baseline performance assessment is completed, the

**Table 1** Three example criteria for urban forest sustainability with associated indicators and key objectives.

| Criteria | Performance indicators | | | | Key objectives |
|---|---|---|---|---|---|
| | Low | Moderate | Good | Optimal | |
| Relative canopy cover | The exiting canopy cover equals 0–25% of the potential. | The existing canopy cover equals 25–30% of the potential. | The existing canopy cover equals 50–75% of the potential. | The existing canopy cover equals 75–100% of the potential. | Achieve climate and region appropriate degree of tree cover, community wide. |
| General awareness of trees as a community resource | Trees seen as a problem, a drain on budgets. | Trees seen as important to the community. | Trees acknowledged as providing environmental, social and economic services. | Urban forest recognised as vital to the community's environmental, social and economic well being. | The general public understanding the role of the urban forest. |
| Tree habitat suitability | Trees planted without consideration of site conditions. | Tree species are considered in planting site selection. | Community-wide guidelines are in place for the improvement and the selection of suitable species | All trees planted in sites with adequate soil quality and quantity, and growing space to achieve their genetic potential. | All publicly owned trees are planted in habiats which will maximise current and future benefits provided to the site. |

planning effort may focus on moving the lowest assessed criteria towards the optimal range. Alternately, managers can choose to prioritise management to address the key objectives that are most closely in line with broader community strategic objectives. Finally, the assessment may serve as an information-gathering exercise; simply going through a collaborative assessment process will provide managers with invaluable insight into the state of the urban forest and the perspectives of other stakeholders.

Criteria and indicators are also a key component of the active adaptive management cycle. Near the end of each five-year management plan's scope, urban forest managers can use the criteria and indicators to evaluate the strategic plan by tracking in which direction the indicators for each criterion have transitioned on the scale, if at all. Then, by comparing where recommendations and resource allocations were initially focused relative to successes and shortcomings, alternative strategies can be developed as required.

## Practical applications of the strategic planning framework

To date, the strategic management planning framework and criteria and indicators have been adopted by several municipalities in southern Ontario, Canada, as part of the process of developing each community's urban forest management plan. Each community's experience has been unique, and the differences in each case highlight the flexibility of the conceptual and temporal framework presented here.

Two distinct examples of the application of the strategic planning framework are the Town of Ajax and the City of Burlington. Located to the east and west, respectively, of the most populous city in Canada – Toronto – both municipalities have dedicated and skilled urban forest managers, but differ in terms of the resources available for urban forestry, with Ajax having the smaller urban forestry programme. Both municipalities undertook the plan development process in 2010, albeit with markedly different approaches.

Ajax's focus was strongly geared towards developing a medium-term plan to improve on-the-ground operations within the first five years, with fewer long-term strategic objectives or recommendations. To this end, much of the up-front consultation, such as visioning sessions and goal-setting, was undertaken by municipal staff internally and with key stakeholders well in advance of developing the plan. In Ajax, the plan development had the benefit of being informed by a recently completed urban forest study that collected and analysed data on overall urban forest cover, structure and species composition. This study developed its recommendations in the context of the urban forests sustainability criteria and indicators (Kenney *et al*., 2011) and highlighted gaps in areas such as tree inventory, canopy cover and leaf area assessment. Criteria and indicators were then recommended for use as part of the urban forest monitoring programme, to be implemented towards the end of the first five-year management plan to inform the subsequent plan.

The City of Burlington adhered more rigorously to a three-level strategic planning framework, with a focus on both short- and medium-term operational improvement as well as more long-term strategic objectives. Consultations were held throughout the planning process, with internal and external stakeholders being given an opportunity to participate extensively in the visioning process, development of strategic priorities and review of recommendations. There was also a strong desire to maintain consistency with the direction of the City's overall strategic plan, which is updated every four years. Unlike in Ajax, a preliminary criteria and indicators assessment was undertaken at the outset of the project, and helped inform the direction of the plan by highlighting key gaps and issues to be addressed. As in Ajax, criteria and indicators also form the main component of the active adaptive management strategy to measure the success of plan recommendations in promoting urban forest sustainability.

Overall, the experiences of developing urban forest management plans for the two communities discussed above, as well as the final products, were quite different. Both municipalities tailored the framework requirements to better suit their needs, illustrating the flexibility of the strategic model. Whereas one community focused more on short- to medium-term operational improvements, and the other on long-term strategic objectives, in neither plan were any key urban forestry issues overlooked or given less than the necessary level of attention or detail. This is due in part to a strategic framework that clearly identifies the important items for all urban forest managers to consider, and outlines the appropriate planning horizons to enable effective management actions to be implemented.

Although this paper focuses on the use of the planning and monitoring framework in the municipal realm, it can also be applied in other urban forest management contexts. The same plan framework has been successfully tailored by other stewards of the urban forest, which, although they manage fewer trees, contend with many similar issues. These have included large landholders such as golf and country clubs. Issues such as cyclical maintenance, tree establishment, protection and risk management, invasive species, and even community stewardship and public awareness, are equally relevant and pressing for such institutions as they are for municipalities, albeit on a smaller scale. Planning horizons may or may not be as long as for municipalities; some courses have elected to shorten their long-term plans to ten years, while others have maintained a 20-year frame of reference.

In the context of golf course tree management, a number of criteria may not be useful, applicable or practical. For instance, assessing the relative canopy cover on golf course grounds has little utility since landscaping needs typically take precedence on such lands and obtaining full canopy cover is not practical. Many other criteria, however, remain as important as they do for municipalities. These include tree species diversity, cooperation with local governments and community buy-in into tree management, among others.

Adoption of this strategic framework and monitoring approach by smaller institutions and landowners further highlights the model's flexibility. Similarly, the framework has been implemented by at least one municipality to neighbourhood scale planning, with city staff and resident representatives working jointly on a steering committee to develop and implement plan recommendations. This pilot project is still in its infancy and the success of this application is yet to be determined, but it holds promise, and the process itself is a good opportunity for neighbourhood residents to become more engaged in their part of the urban forest. The same community is looking for ways to tailor the criteria and indicators approach to undertaking a gap analysis for management of a significant natural area. It is anticipated that many of the current criteria will need to be replaced, while some will be equally applicable as they are to urban forest management.

## Concluding remarks

In this paper, we have presented a temporal and contextual framework for strategic urban forest management planning and reviewed how a comprehensive monitoring framework can be integrated into the plan development and review process.

The three-tiered framework is well suited to addressing the challenges faced by urban forests through planning for at least three reasons. Firstly, it enables real linkages between long-term, high-level strategic objectives and daily on-the-ground management and maintenance activities, by way of intermediate management plans. Secondly, it is flexible enough to enable a community, or others involved in planning, to tailor it to suit their needs, while ensuring that important issues are not overlooked. Thirdly, with built-in mechanisms to ensure adaptive management by way of management plan review, progress towards achieving urban forest sustainability is, if not ensured, then greatly enhanced. With the integration of criteria and indicators, this planning approach effectively addresses urban forest management and sustainability issues on a long-term horizon.

The challenges to urban forests are clear and undeniable. It is our hope that more communities, institutions and landowners recognise the value of a strategic and collaborative approach to urban forest planning so that future generations might enjoy all of the important benefits that trees provide us with today.

## References


2DEGREESC (2007). *Climate change: Impacts and adaptations for terrestrial and aquatic ecosystems and species in the Credit Valley*. Credit Valley Conservation, Guelph, Ontario.

CLARK, J.R., MATHENY, N.P., CROSS, G. AND WAKE, V. (1997). A model of urban forest sustainability. *Journal of Arboriculture* **23**(1), 17–30.

COLOMBO, S.J. (2008). *Ontario's forests and forestry in a changing climate*. CCRR-12, Applied Research and Development Branch, Ontario Ministry of Natural Resources.

DONOVAN, G.H. AND BUTRY, D.T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning* **94**, 77–83.

DWYER, J., MCPHERSON, E., SCHROEDER, H. AND ROWNTREE, R. (1992). Assessing the benefits and costs of the urban forest. *Journal of Arboriculture* **18**, 227–234.

GALATOWITSCH, S., FRELICH, L. AND PHILLIPS-MAO, L. (2009). Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America. *Biological Conservation* **142**, 2012–2022.

KENNEY, W.A., VAN WASSENAER, P.J.E. AND SATEL, A.L. (2011). Criteria and indicators for sustainable urban forest management. *Arboriculture and Urban Forestry* **37**, 118–125.

KUO, F. (2003). Social aspects of urban forestry: the role of arboriculture in a healthy social ecology. *Journal of Arboriculture* **29**(3), 148–155.

MCPHERSON, E. (1994). Energy-saving potential of trees in Chicago. *In*: McPherson, E., Nowak, D. and Rowntree, R. (eds.) *Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project*. Gen. Tech. Rep. NE-186. US

Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania.
MILLENNIUM ECOSYSTEM ASSESSMENT (2005). *Global assessment reports*. World Resources Institute, Washington, DC.
MOLL, G. AND EBENRECK, S. (1989). *Shading our cities*. Island Press, Washington, DC.
SIMPSON, J.R. (1998). Urban forest impacts on regional cooling and heating energy use: Sacramento County case study. *Journal of Arboriculture* **24**(4), 201–214.
UNFPA (2010). *State of the world population. From conflict and crisis to renewal: generations of change*. United Nations Population Fund, New York.
URBAN, J. (2008). *Up By Roots: Healthy soils and trees in the built environment*. International Society of Arboriculture, Champaign, IL.
VAN WASSENAER, P.J.E., SCHAEFFER, L. AND KENNEY. W.A. (2000). Strategic planning in urban forestry: A 21st century paradigm shift for small town Canada. *The Forestry Chronicle* **76**(2), 241–245.
WOLF, K. (2004). Economic and public value of urban forests. *Urban Agriculture Magazine* **13**, 31–33.

# Results of a long-term project using controlled mycorrhization with specific fungal strains on different urban trees

## Abstract

Several research projects have been undertaken in the past years to identify the effects of mycorrhiza, which include increased water and nutrient uptake, and protection against drought, salinity, heavy metals and pathogens (Augè, 2001) on widely planted shade trees. However, most experiments were carried out under conditions different to those commonly found in the urban environment. The aim of this work was to investigate the effect of different strains of mycorrhizae-forming fungi specifically selected for the urban environment in different situations (i.e. urban and historical parks, parking lots, boulevards) usually found in cities all over the world. The project began in 2006 and was carried out on several of the most widely planted shade tree species of different ages ranging from newly planted to mature trees located in our historical parks. Trees were inoculated with specific mycorrhyzal inoculi according to species and environmental conditions. Different growing conditions were tested ranging from trees growing in a parking lot, to trees growing in historical or peri-urban parks. Results obtained to date have been variable according to species and environmental conditions. Some of the test species (i.e. *Celtis australis*) responded quickly to mycorrhizal fungi that were extremely effective in increasing plant growth and leaf gas exchange. Other species (i.e. *Tilia* spp.) showed a different response according to plant age and planting site. Other species (i.e. *Fraxinus excelsior*) had a slow response to mycorrhyzal inoculation. In general there has been a positive (sometimes very strong) response to mycorrhizal inoculation and further data will be harvested in 2011.

## Introduction

Mycorrhizae-forming fungi are ecologically significant because they form relationships in and on the roots of a host plant in a mutualistic association. The host plant provides the fungus with soluble carbon sources, while the fungus provides the plant with several benefits including enhanced nutrient, especially phosphorus, uptake (Yao *et al.*, 2001; Habte, 2006); protection against drought through increased water use efficiency and enhanced root exploration of the available soil volume (Espeleta *et al.*, 1999; Augè, 2001; Kaya *et al.*, 2003); and reduction in disease incidence (Thygesen *et al.*, 2004), pathogen development (Cordier *et al.*, 1996) and disease severity (Matsubara *et al.*, 2001). It has been reported that mycorrhiza protect the host plant from heavy metals (Smith and Read, 1997; Joner *et al.*, 2000) and salinity by protecting cell membrane integrity through higher root accumulation of P and $Ca^{2+}$ and by increasing the efficiency of sodium-excluding mechanisms in infected roots (Mancuso and Rinaldelli, 1996; Rinaldelli and Mancuso, 1996). However, the urban environment is markedly different from natural and forest environments where mycorrhizal fungi have evolved and adapted and, consequently, the ecological distribution of fungi is probably altered in an urban environment. Recent work analysed mycorrhizal colonization patterns of *Tilia* grown in the urban, nursery and forest environment (Timonen and Kauppinen, 2008). They showed that healthy street and forest trees had higher number of mycorrhiza morphotypes than unhealthy urban trees. Surprisingly, none of the mycorrhizal fungi found in the nursery were found in the urban environment, suggesting that the nursery genotypes are either not adapted to street conditions or they are outcompeted as transplanted trees establish a more mature mycorrhizosphere (Timonen and Kauppinen, 2008). Since drought, use of de-icing salts, lack of nutrients and attack from pathogens are among the main causes of failure of urban trees (Fini and Ferrini, 2007), the inoculation of urban trees with selected, native, competitive and effective mycorrhiza may enhance tree growth and survival in the urban environment. However, studies

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regarding mycorrhizal inoculation of urban trees in Europe are few. The aim of this project was to evaluate the effect of inoculation with selected native mycorrhizal fungi on trees growing in a street environment, in a parking lot and in an historical and peri-urban park. The results are a part of a long-term research project started in 2006 with an initial inoculation and that will conclude in 2011.

# Material and methods

## Selection, propagation and distribution of the mycorrhizal fungi

Selection, multiplication and distribution of the specific mycorrhizal inocula were as described in Fini *et al.* (2011). Briefly, five to seven healthy mature trees growing in the urban and peri-urban environment were selected and fine roots were sampled by digging holes around the tree. Holes were deep and wide as required to harvest a sufficient amount of fine, absorbing root. Trees were selected on the basis of the following criteria: 1) health; 2) age; 3) same species as the trees to be inoculated; 4) similar environmental conditions to those of the site where the inoculum had to be distributed. Each sample weighed approximately 500 grams of roots + soil. Root samples were analysed at the MycoMax laboratory (MykoMax Gmbh, Wuppertal, Germany). Mycorrhizal species were isolated and multiplied in a greenhouse in non-sterile conditions following the procedure developed by MycoMax in agreement with German FLL standards for mycorrhiza inoculation. Criteria for the selection of mycorrhizal fungi were: 1) frequency of mycorrhizal root tips (ecto-) or intensity of root colonization (VAM); 2) structure and vitality of the Hartig net (ecto-) or arbuscules (VAM); 3) phosphatase activity (VAM). After at least eight months of culture on living and viable roots, roots containing fungal mycelium were harvested and mixed with montmorillonite clay and a hydro-gel to maximize durability. The fungal inoculum was distributed within one month of its production. Three holes exposing the absorbing roots of the tree to be inoculated were dug for each 10 cm of stem diameter (measured at 1.3 m trunk height) of the tree to inoculate. 125 ml of product were placed in each hole to ensure contact between fungal mycelium and absorbing tree roots. Holes were quickly re-filled with a shovel.

## Container-grown trees in nursery production

A total of 80 two-year-old hedge maples (*Acer campestre* L.), 80 littleleaf lindens (*Tilia cordata* Mill.) and 80 pedunculate oaks (*Quercus robur* L.) were potted in 3 litre containers using a peat:pumice (3:1) substrate amended with 3 kg m$^{-3}$ dolomite to neutralize pH. A reduced dose (1 kg m$^{-3}$) of a controlled release fertilizer (Ficote®, 15–3, 5–10, 8–9 months formulation, Scotts, Marysville, OH) was used in this experiment to avoid an excessive soil chemical fertility which may decrease mycorrhizal colonization. Container capacity, wilting point and effective water holding capacity of the substrate was determined using the gravimetric method described by Sammons and Struve (2008). 40 plants per species were inoculated with specific mycorrhizal fungi (ECM in oak, VAM in maple and both ECM and VAM in linden). Inoculation was done on March 2008 using 25 ml of inoculum per plant. Plants were either irrigated daily in order to restore container capacity, well watered (WW) or irrigated daily to 30% of container water capacity, water shortage (WS). The experimental was a randomized block design with 6 blocks and 5 plants per species and treatment in each block.

## Trees from the nursery to the landscape: plant material and growing conditions

A total of 48 plants (14–16 cm circumference) were selected in Lappen Nurseries (Nettetal, Germany) in winter 2007. In April 2007, 24 plants were inoculated ($+I_N$) with specific ecto- and endomycorrhizal fungi selected in Milan urban area and the remaining 24 plants were not ($-I_N$). In May 2008, all plants were root pruned. Then, plants were grown in the nursery until early spring 2010, when they were moved to Milan. At transplanting, half of the plants were inoculated with the same fungi as in 2007 ($+I_T$) and the remaining half were not ($-I_T$). Therefore, four treatments were compared: 1)$+I_N+I_T$: plants inoculated both in the nursery and at transplant; 2) $+I_N-I_T$: plants inoculated in the nursery but not at transplant; 3) $-I_N+I_T$: plants inoculated only at transplant; 4)$-I_N-I_T$: control plants (never inoculated). Plants were arranged with a factorial randomized block design with 8 blocks and 4 plants per block.

## Young trees in urban parks

In November 2005, 62 pedunculate oaks (*Quercus robur*; 10–12 cm circumference) were planted in two rows in an urban park in San Donato Milanese (Milan, Italy). Distance between plants was 8 m within the row and 8 m between the rows. 24 trees were inoculated with selected specific ecto-mycorrhizal fungi and 24 were not inoculated. Inoculation was performed in November 2006, approximately one year after planting. Trees were arranged in a randomized block design with 3 blocks and 8 plants per treatment within each block. 14 remaining oaks were used to separate, on the row, inoculated and control plants, to reduce the risk of unwanted contamination on non-inoculated plants.

## Trees in parking lots: plant material and growing conditions

In November 2005, 24 European hackberry (*Celtis australis*; 14–16 cm circumference) were planted in a parking lot in San Donato Milanese (Milan, Italy). Trees were planted in a planting hole with an unpaved surface of about 0.5 $m^2$, surrounded by asphalt and concrete. Trees were arranged in a randomized complete block design with 6 blocks and 2 plants per treatment within each block. 12 trees were inoculated with species-specific, native strains of ectomycorrhizal fungi, and 12 trees were not inoculated and acted as controls. Inoculation was undertaken in November 2006, approximately one year after planting.

## Street trees: plant material and growing conditions

In spring 2004, 20 European ashes (*Fraxinus excelsior* 'Westhof's Glorie'; 20–25 cm circumference) were planted along a street characterized by high traffic and pollution, located in Florence (Italy). The size of the planting hole was about 1 $m^2$. Trees were planted in a randomized complete block design with 5 blocks. 10 trees were inoculated with species-specific strains of endomycorrhizal fungi and 10 trees acted as control. Inoculation was in April 2006.

## Trees in a historical park: plant material and growing conditions

In autumn 2006, 14 mature European linden (*Tilia x europaea*; 170–220 cm circumference) and 14 mature horse chestnut (*Aesculus hippocastanum*; 120–160 cm circumference) were selected in a historical park located in the city-centre of Milan. 14 additional newly planted *Tilia x europaea* (18–20 cm circumference) and 14 *Aesculus hippocastanum* (20–25 cm circumference) were selected in the same location. Trees were planted in a heavily compacted soil. The experimental set-up was a complete randomized design using a single tree per replicate and 7 replicates. 7 mature and 7 young trees of each species were inoculated with selected native and species-specific strains of both ecto- and endomycorrhiza (linden) or with endo-mycorrhizal fungi (horse chestnut). Inoculation was in November 2006.

## Measurements of tree growth and vitality

One year after inoculation, a sample of fine root + soil was harvested from inoculated and control trees. Samples were harvested from one (historical park, street trees) or two (nursery) plants per treatment and replication. Roots were carefully separated from the soil and cut into 1 cm long pieces. Frequency of ectomycorrhizal roots was measured on 200 root tips as the ratio of mycorrhizal root tips to total root tips (Newton and Pigott, 1991). To evaluate VAM colonization, roots were stained using 0.05% Trypan blue in lactoglycerol (Koske and Gemma, 1989). Percentage of root colonization was measured by counting cross-hair intersections using a stereomicroscope (McGonigle *et al.*, 1990).

Biomass of container-grown plants was determined after two years from inoculation (2009). To measure biomass, plants were cut at the root flare, roots were cleaned with a flush of compressed air and leaves were excised from stems. Roots, stems and leaves were then oven-dried at 70°C for 72 hours and weighted separately to determine dry weight. Biomass of field-grown trees was estimated measuring shoot and diameter growth. According to the different experiments, the following parameters were measured during the entire duration: Shoot growth was on 20 shoots per treatment per replicate. Stem diameter was measured at 1.3 m trunk height.

Leaf gas exchange was generally measured on three fully expanded leaves per treatment and block/replicate with an infrared gas analyser (Ciras-2, PP-System, Hertfordshire, UK). Measures were taken at saturating (1300 mol $m^{-2}$ $s^{-1}$) light intensity, ambient temperature and 360 ppm $CO_2$. Water use efficiency was calculated as the A to E ratio (Fini *et al.*, 2009). Chlorophyll fluorescence was measured with a portable Plant Efficiency Analyzer (Hansatech Instruments Ltd, King's Lynn, UK) on the same leaves as gas exchange. Fluorescence values were obtained after adapting leaves to darkness for 30 min by attaching light-exclusion clips to the leaf surface of whole trees. Upon the application of a saturating flash of actinic light (3000 mol $m^{-2}$ $s^{-1}$ for 1 sec), fluorescence raises from the ground state value ($F_o$) to its maximum value, $F_m$. This allows the determination of the maximal quantum yield of PSII (Fv/Fm).

Chlorophyll content was measured two times during the growing season in 2007 (only on *Fraxinus excelsior*) and 2008 with a SPAD-meter (Konica Minolta Holding Inc., Tokyo, Japan). Nine measurements per treatment per replicate were undertaken. Readings were taken in the medial section of the lamina, taking care not to include leaf veins in the measurement chamber.

## Statistics

All data were analysed with one- or two-way ANOVA using the SPSS statistical package for Windows (SPSS Inc., Chicaco, IL, USA). Differences between means were determined using Duncan's Multiple Range Test.

# Results and discussion

## Root colonization in inoculated and control plants

Inoculation with selected mycorrhiza increased root colonization in container-grown maples, lindens and oaks (Table 1). Even if control trees were not inoculated, some mycorrhiza were also found on their roots. Morphotyping of control plant roots classified these mycorrhiza as 'nursery mycorrhiza' (Fini *et al*., 2011). It is common to find 'nursery mycorrhiza' on nursery stock, and in any case these fungal species have been reported to be unable to thrive and provide benefits to the host tree in urban conditions (Timonen and Kauppinen, 2008). Similarly, inoculation of oak trees in an urban park increased the frequency of mycorrhizal root tips. This indicates the ability of selected fungal strains to compete with native microorganisms and efficiently form a symbiotic relationship, even when the native mycorrhizal population is well developed (control had 76% colonized root tips; Table 1). The endomycorrhizal inoculum developed for ash was found to be effective in street environments, even in those characterized by a well-developed native mycorrhiza population. This is important because native mycorrhizal populations are likely to provide lower benefits to plants than selected fungal strains. If fungi in the inoculum are quickly outcompeted by native microorganisms or their infection is slowed down by adverse environmental conditions, colonization of the host plant is reduced and little or no benefit can be expected from inoculation. Possibly this was the case for the newly planted lindens and horse chestnuts in a historical park where poor soil conditions such as heavy soil compaction and lower carbon availability for the mycorrhizal fungus due to lower carbon assimilation (thus lower availability of C to support fungal growth and activity) of newly planted trees resulted in a low inoculum efficacy (Nadian *et al.*, 1997). When the same ECM (linden) and VAM (horse chestnut) inocula were used on mature, established trees, root colonization was increased (Table 1).

Table 1 Percentage of colonization by ectomycorrhizal and endomycorrhizal fungi in inoculated and non-inoculated tree species planted in the nursery or in different urban sites.

| Site | Species | Treatment | % colonization (ECM) | % colonization (VAM) |
|---|---|---|---|---|
| Nursery (in container) | *Acer campestre* | Inoculated | - | 53% |
| | | Control | - | 24% |
| | | P | - | ** |
| | *Tilia x europaea* | Inoculated | 81% | 17% |
| | | Control | 59% | 10% |
| | | P | ** | * |
| | *Quercus robur* | Inoculated | 80% | - |
| | | Control | 41% | - |
| | | P | ** | - |
| Urban park | *Quercus robur* | Inoculated | 85% | - |
| | | Control | 76% | - |
| | | P | ** | - |
| Street trees | *Fraxinus excelsior* | Inoculated | - | 81% |
| | | Control | - | 71% |
| | | P | - | * |
| Historical park | *Aesculus hippocastanum* (newly planted) | Inoculated | - | 59% |
| | | Control | - | 51% |
| | | P | - | n.s. |
| | *Aesculus hippocastanum* (mature trees) | Inoculated | - | 76% |
| | | Control | - | 63% |
| | | P | - | ** |
| | *Tilia x europaea* (newly planted) | Inoculated | 45% | 37% |
| | | Control | 44% | 28% |
| | | P | n.s. | n.s. |
| | *Tilia x europaea* (mature trees) | Inoculated | 49% | 39% |
| | | Control | 36% | 32% |
| | | P | * | n.s. |

Data were collected one year after inoculation. * and ** indicate significant differences between treatments within the same species and planting site at $P<0.05$ and $P<0.01$

## Container-grown trees in nursery production

Inoculation with specific mycorrhiza did not enhance biomass accumulation of maple, linden and oak saplings growing in containers (Table 2). Plants growing in water-stressed conditions had lower leaf, stem and root (except for oak) dry weights than well-watered plants of the same species, regardless of whether inoculated or not (Table 2). Similar results were found by other authors on several landscape trees (Gilman, 2001; Wiseman and Wells, 2009). Induction of greater stress tolerance and therefore the possibility to grow nursery crops with lower resource input has been reported as the major benefit of mycorrhizal technology in plant production systems (Davies, 2000). In 2009, water-stressed inoculated plants of maple and linden showed higher carbon assimilation and similar transpiration rates and therefore higher water use efficiency than water-stressed control plants (Table 3). Water-stressed inoculated oak had higher transpiration and similar carbon assimilation and water use efficiency than controls. In well-watered conditions, differences between inoculated and control maple and linden were not significant (except for assimilation in maple). Data indicated that in optimal conditions the benefits of mycorrhiza are not always conclusive. The inoculation-induced increase in photosynthetic rate and water use efficiency may become clearer under stress conditions and this may play a major role in determining plant survival when plants are moved from the optimal growing conditions of a nursery to the suboptimal or stressful conditions of an urban environment.

## Trees from the nursery to the landscape

Inoculation had no effect on stem diameter growth during the nursery period (2007–2009) and in the first year after planting into the landscape (2009–2010: Table 4). In 2007, inoculation had no effect on shoot growth. In May 2008, roots were pruned in the nursery according to best management practices and this resulted in some degree of stress to linden trees, as shown by a large decrease in shoot growth in 2008 compared to 2007. When above-ground growth was limited by root pruning, inoculation with

Table 2 Effects of inoculation, water stress and their interaction on leaf, stem and root dry weights (DW, g) in inoculated and control *Acer*, *Tilia* and *Quercus* growing in containers in well-watered (WW) or water shortage (WS) conditions.

| 2009 | *Acer* | | | *Tilia* | | | *Quercus* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Leaf DW | Stem DW | Root DW | Leaf DW | Stem DW | Root DW | Leaf DW | Stem DW | Root DW |
| | | | | | *Effect of inoculation* | | | | |
| Mycorr. | 35.1 | 92.9 | 120.3 | 19.9 | 64.8 | 75.6 | 30.0 | 84.3 | 75.2 |
| Control | 32.3 | 90.2 | 116.4 | 19.3 | 63.3 | 70.7 | 28.0 | 83.0 | 88.7 |
| P | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| | | | | | *Effect of water stress* | | | | |
| WW | 38.1 | 111.5 | 142.4 | 22.9 | 77.6 | 89.8 | 34.2 | 111.4 | 88.1 |
| WS | 29.3 | 71.6 | 94.3 | 16.3 | 60.5 | 56.6 | 24.0 | 55.6 | 75.9 |
| P | * | ** | ** | ** | ** | ** | ** | ** | n.s. |
| | | | | | *Inoculation x water stress* | | | | |
| P | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |

* and ** indicate significant differences between treatments within the same species at P<0.05 and P<0.01.

Table 3 Effects of inoculation, water stress and their interaction on carbon assimilation (A, µmol $m^{-2}$ $m^{-1}$), transpiration (E, mmol $m^{-2}$ $m^{-1}$) and water use efficiency (WUE, µmol $CO_2$/mmol $H_2O$) in inoculated and control *Acer*, *Tilia* and *Quercus* growing in containers in well-watered (WW) or water shortage (WS) conditions.

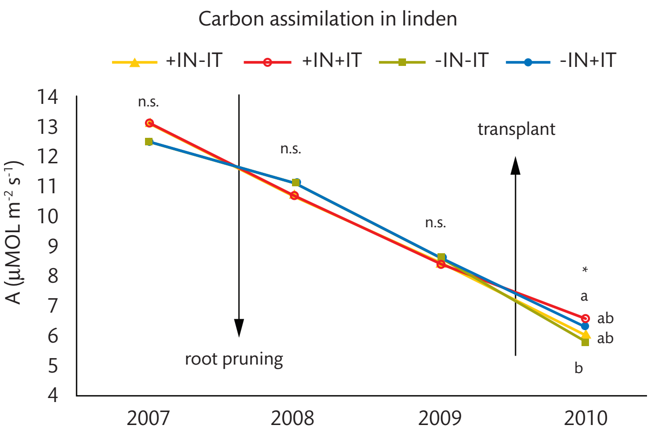
| 2009 | *Acer* | | | *Tilia* | | | *Quercus* | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | E | WUE | A | E | WUE | A | E | WUE |
| Myco. WW | 9.24 a | 3.07 a | 3.01 b | 7.12 a | 3.55 a | 2.01 ab | 10.90 a | 3.99 a | 2.74 |
| Contr. WW | 7.64 b | 2.87 a | 2.66 b | 6.15 a | 3.17 a | 1.94 ab | 11.43 a | 4.11 a | 2.78 |
| Mico. WS | 4.27 c | 1.05 b | 4.08 a | 3.38 b | 1.33 b | 2.57 a | 8.08 ab | 2.57 b | 3.15 |
| Contr. WS | 1.60 d | 0.62 c | 2.58 b | 1.11 c | 0.75 b | 1.50 b | 5.09 b | 1.73 c | 2.95 |
| P | ** | ** | ** | ** | ** | ** | ** | ** | n.s. |

Data are the average of two samplings done in 2009. Different letters within the same column indicate significant differences between treatments at P<0.01.

selected mycorrhiza resulted in significantly longer shoots than with untreated plants (Table 4). One year after root pruning (2009), shoot growth recovered to levels similar to 2007 and no significant differences between treatments were recorded. Lindens were transplanted into the urban environment in spring 2010. Transplant stress occurred in the following growing season and greatly reduced shoot growth (Table 4). Again, when stress occurred, an inoculation-induced increase in shoot growth was found. In particular, shoot growth was higher in plants inoculated in the nursery and both in the nursery and at planting when compared to control and plants inoculated only at planting (Table 4).

Carbon assimilation was not affected by inoculation with specific mycorrhiza during the nursery phase, even after a root pruning treatment (Figure 1). After planting in the landscape, plants inoculated both in the nursery and at planting showed higher carbon assimilation than non-inoculated control plants. Inoculating plants both in the nursery and at transplanting possibly contributed to a greater root colonization by mycorrhizal fungi, which resulted in higher photosynthetic rates. Transpiration, stomatal conductance and water use efficiency were little affected by mycorrhizal treatment, during both the nursery period and after transplanting (data not shown). Therefore, we can speculate that trees inoculated both in the nursery and at planting had a higher photosynthesis on a plant-scale basis (higher A) and this may have contributed to greater shoot growth. Previous research in this area has shown that whole-plant photosynthetic rate under resource-unlimited conditions is proportional to shoot growth and leaf area (de Palma *et al.*, 2004).

**Figure 1** Carbon assimilation (A, µmol m$^{-2}$ s$^{-1}$) in linden inoculated in the nursery ($+I_N-I_T$), in the nursery and at transplanting ($+I_N+I_T$), not inoculated ($-I_N-I_T$) and inoculated only at transplant ($-I_N+I_T$). Different letters within the same sampling date indicate significant differences at P<0.05.




## Young trees in an urban park

Stem diameter growth of newly planted pedunculate oak (*Quercus robur*) was not affected by inoculation with selected specific ectomycorrhiza throughout the experiment (Table 5). Shoot growth was increased by inoculation in the first growing season after inoculation, although shoot growth was very low due to transplant stress (Table 5). In 2008 and 2009 shoot growth was significantly greater in inoculated oaks when compared to control, which indicates a beneficial influence of mycorrhizal inoculation regarding the establishment of oak trees. Even after establishment, differences between treatments were confirmed and inoculated plants showed higher shoot growth in both 2008 and 2009 compared to control plants (Table 5). SPAD values were higher in inoculated plants in both years. Recent papers on some woody species showed that SPAD readings are highly correlated to leaf chlorophyll content (measured using traditional destructive methods) ($R^2$>0.82), leaf carotenoids ($R^2$>0.82) and leaf N-content ($R^2$>0.53) (Luh *et al.*, 2002; Percival *et al.*, 2008). Therefore, higher SPAD readings in treated leaves may indicate a higher nutritional status of inoculated oaks than control ones when planted into an urban park. After September 2008, carbon

**Table 4** Effect of inoculation in the nursery phase and/or at planting with specific mycorrhiza on linden trees growing in the nursery (2007–2009) and after transplant in the landscape (2010). In 2008 trees were root pruned to prepare them for transplant.

| Inoculation | | ΔØ (cm) | | | Shoot growth (cm) | | | |
|---|---|---|---|---|---|---|---|---|
| Nursery | Transplant | 07/08 | 08/09 | 09/10 | 2007 | 2008 | 2009 | 2010 |
| $+I_N$ | $-I_T$ | 0.58 | 0.74 | 0.20 | 51.89 | 9.78 a | 45.75 | 8.21 a |
| | $+I_T$ | | | 0.33 | | | | 7.81 a |
| $-I_N$ | $-I_T$ | 0.47 | 0.71 | 0.30 | 56.08 | 6.56 b | 42.55 | 6.28 b |
| | $+I_T$ | | | 0.35 | | | | 5.84 b |
| P | | n.s. | n.s. | n.s. | n.s. | ** | n.s. | ** |

Different letters within the same column indicate significant differences between treatments at P<0.01.

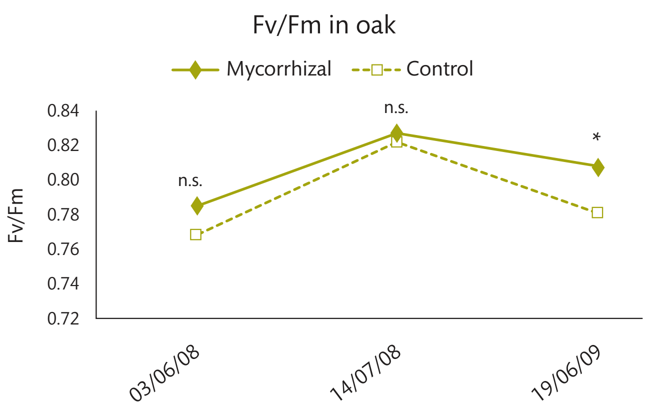
Table 5 Effects of inoculation with selected ectomycorrhiza on diameter and shoot growth and on chlorophyll content of *Quercus robur* planted in an urban park.

| ***Quercus robur*** | **ΔØ (cm)** | | | **Shoot growth (cm)** | | | **Chlorophyll content (SPAD)** | |
|---|---|---|---|---|---|---|---|---|
| | **06/07** | **07/08** | **08/09** | **2007** | **2008** | **2009** | **June 2008** | **Sept. 2008** |
| Mycorrhiza | 0.70 | 1.30 | 1.43 | 13.52 | 68.22 | 71.4 | 43.2 | 43.6 |
| Control | 0.52 | 1.27 | 1.27 | 4.13 | 41.38 | 48.8 | 39.1 | 39.8 |
| P | n.s. | n.s. | n.s. | ** | ** | ** | * | ** |

* and ** indicate significant differences between mycorrhizal and control trees of the same species at P<0.05 and P<0.01.

assimilation was generally higher in inoculated oaks, even if significant differences were found only on 18 May 2009 (Figure 2, left). Also, when significant differences were found, inoculated plants had higher WUE than non-inoculated ones (Figure 2, right). Higher WUE in plants inoculated with selected fungal species were also found in other work and were attributed to stomatal and nutritional effects induced by inoculation (Guehl and Garbaye, 1990; Guehl *et al.*, 1990; Dunabeitia *et al.*, 2004). Taking into consideration that WUE is one of the main growth determining factors in potentially harsh sites such as a urban environments, results obtained in the third growing season after inoculation suggest that ectomycorrhizal colonization may increase long-term tolerance to water stress. Fv/Fm was not affected by inoculation in 2008, and Fv/Fm was higher than 0.80 in both treatments, a value indicative of healthy plants (Percival, 2005; Figure 3). In 2009, inoculated plants had higher Fv/Fm than non-inoculated plants. The higher maximum yield of PSII (Fv/Fm values) measured in 2009 in inoculated plants may explain the higher gas exchange values found in treated oaks in 2009.

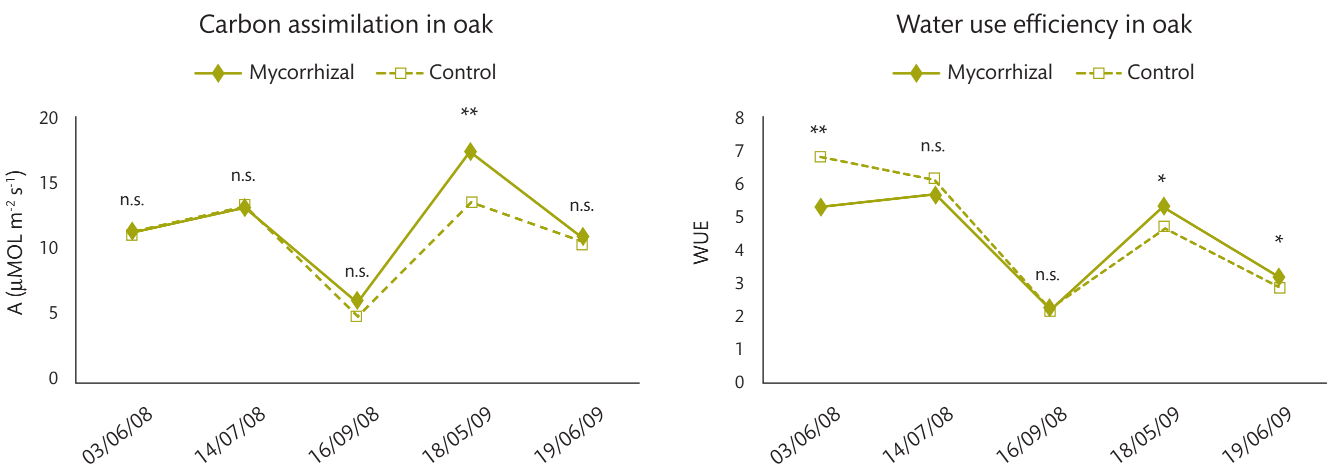
Figure 3 Maximal quantum yield of photosystem II (Fv/Fm) in inoculated and non-inoculated pedunculate oaks planted in an urban park. * indicates significant differences between mycorrhizal and control trees within the same sampling date at P<0.05.




## Street trees and trees growing in a parking lot

Inoculation with local strains of species-specific mycorrhizal fungi increased stem diameter growth in young, newly planted European hackberry, growing in a parking lot

Figure 2 Carbon assimilation (A, µmol m$^{-2}$ s$^{-1}$, left) and water use efficiency (WUE, mol $CO_2$/mmol $H_2O$, right) in inoculated and non-inoculated pedunculate oaks planted in an urban park. * and ** indicate significant differences between mycorrhizal and control trees within the same sampling date at P<0,05 and P<0,01.



(Table 6). Significant differences in stem diameter annual growth between inoculated and non-inoculated plants were found both in the first and the second year after inoculation, but not in the third. Inoculation with German, species-specific endomycorrhiza for *Fraxinus excelsior* failed to increase diameter growth in ash trees growing along a road (Table 6). Effect of mycorrhiza on shoot growth was highly significant in 2007 and 2008 in ash and in 2007, 2008 and 2009 in European hackberry (Table 6). Mycorrhizal inoculated ashes had 48% and 42% longer shoots than control trees in 2007 and 2008, respectively. Shoots of mycorrhizal inoculated hackberries were 55%, 98% and 80% longer than those of non-inoculated control trees in 2007, 2008 and 2009, respectively.

Mycorrhizal inoculation increased carbon assimilation and water use efficiency of hackberry in all sampling dates, except in September 2008 (Figure 4). Five months after inoculation (September 2006), no difference in carbon assimilation and water use efficiency was found between mycorrhizal inoculated and non-inoculated control ashes (Figure 5). In 2007, mycorrhizal inoculated ashes had both higher assimilation and water use efficiency than non-inoculated plants, with significant differences confirmed in 2008 (Figure 5). Therefore, possibly, the inoculation-induced increase in WUE allowed mycorrhizal trees to fix more carbon dioxide per unit of transpired water, thus giving greater carbohydrate availability for growth and defence. The maximal quantum yield of photosystem II (Fv/Fm) is a widely used index for measuring plant vitality and early diagnostic measure of stress (Willits and Peet, 2001). Fv/Fm measurement of healthy, unstressed plants is associated with values ranging from 0.75 to 0.85 (Percival, 2005). Both control and inoculated hackberries consistently showed higher Fv/Fm values than 0.75, which indicated a high adaptability of this species to difficult planting sites such as a parking lot. Inoculated plants had significantly higher Fv/Fm values than control plants in July 2008 and June 2009 (Figure 6). This indicated that the phytochemistry of photosystem II was improved by mycorrhizal inoculation, which can result from lower oxidative damage within chloroplasts and/or from a better nutritional status of the leaves. Chlorophyll content was higher in mycorrhizal inoculated hackberries compared to control plants both at the middle and at the end of the growing season (Table 6). The higher SPAD-value measured in mycorrhizal inoculated hackberries reflects a higher nutritional status of plants compared to non-inoculated controls, when grown in a stressful environment such as a parking lot (Luh *et al.*, 2002; Percival *et al.*, 2008). No difference in leaf chlorophyll content and Fv/Fm (data not shown) were found between treatments in *Fraxinus* (Table 6).

## Trees in a historical park

In 2006–2007, stem diameter growth was unaffected by mycorrhizal inoculation on both young and mature linden and horse chestnut (Table 7). Mature trees of both species had greater stem diameter growth than newly planted trees. In 2007–2008 mycorrhizal inoculation increased stem diameter growth in mature lindens, but had no significant effect on young trees. In the second year mycorrhizal inoculated mature lindens had 318% higher diameter growth than untreated control. No difference among treatments was found in horse chestnut. In 2008–2009, stem diameter growth of linden trees was similar among treatments, while it was significantly higher in young horse chestnut than in mature ones (Table 7). In 2008, shoot growth was significantly increased by inoculation in mature lindens and horse chestnuts, which had 20% and 55% longer shoots than control trees, respectively (Table 7). No significant difference was found for shoot growth in newly planted linden and

Table 6 Effects of inoculation with selected mycorrhiza on diameter and shoot growth and on chlorophyll content of *Celtis australis* and *Fraxinus excelsior* planted in a parking lot and along a street, respectively.

| | ΔØ (cm) | | | Shoot growth (cm) | | | Chlorophyll content (SPAD) | |
|---|---|---|---|---|---|---|---|---|
| ***Celtis australis*** | **06/07** | **07/08** | **08/09** | **2007** | **2008** | **2009** | **June 2008** | **Sept. 2008** |
| Mycorrhiza | 0.57 | 1.26 | 0.45 | 23.86 | 30.33 | 36.55 | 45.37 | 48.77 |
| Control | 0.30 | 1.07 | 0.37 | 15.40 | 15.25 | 20.25 | 39.06 | 35.68 |
| P | ** | * | n.s. | ** | ** | ** | ** | ** |
| ***Fraxinus excelsior*** | **06/07** | **07/08** | **08/09** | **2007** | **2008** | **2009** | **2007** | **2008** |
| Mycorrhiza | N.D. | 0.71 | N.D. | 7.05 | 10.12 | N.D. | 29.04 | 30.10 |
| Control | N.D. | 0.88 | N.D. | 4.76 | 7.11 | N.D. | 30.03 | 30.40 |
| P | - | n.s. | - | ** | ** | - | n.s. | n.s. |

* and ** indicate significant differences between mycorrhizal and control trees of the same species at P<0.05 and P<0.01. N.D. = not determined.

**Figure 4** Carbon assimilation (A, µmol m$^{-2}$ s$^{-1}$, left) and water use efficiency (WUE, µmol $CO_2$/mmol $H_2O$, right) in inoculated and non-inoculated hackberry trees planted in a parking lot. * and ** indicate significant differences between mycorrhizal and control trees within the same sampling date at P<0.05 and P<0.01.

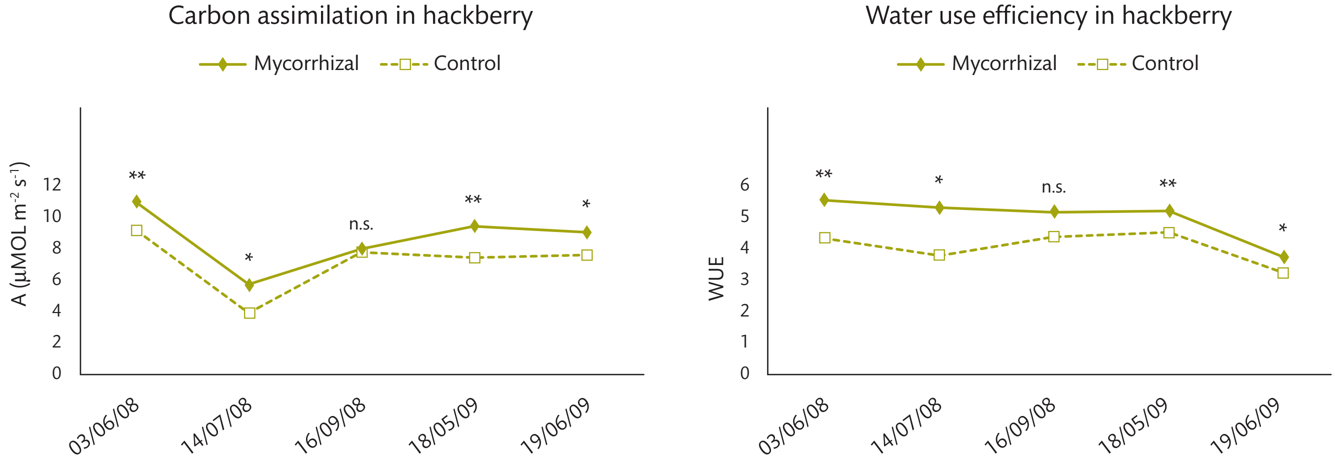



**Figure 5** Carbon assimilation (A, µmol m$^{-2}$ s$^{-1}$, left) and water use efficiency (WUE, µmol $CO_2$/mmol $H_2O$, right) in inoculated and non-inoculated ash trees planted as street trees. * and ** indicate significant differences between mycorrhizal and control trees of the same species at P<0.05 and P<0.01.

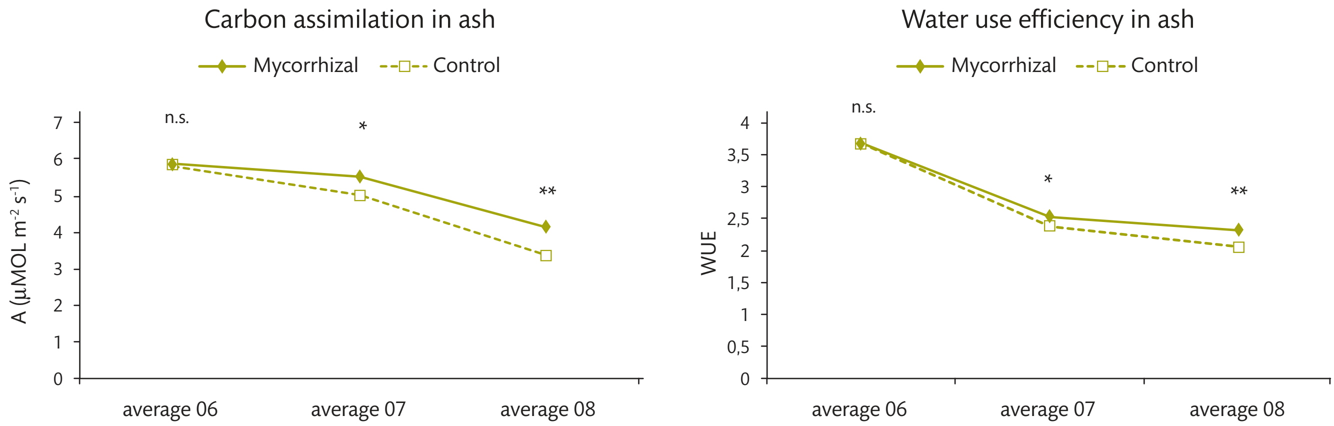
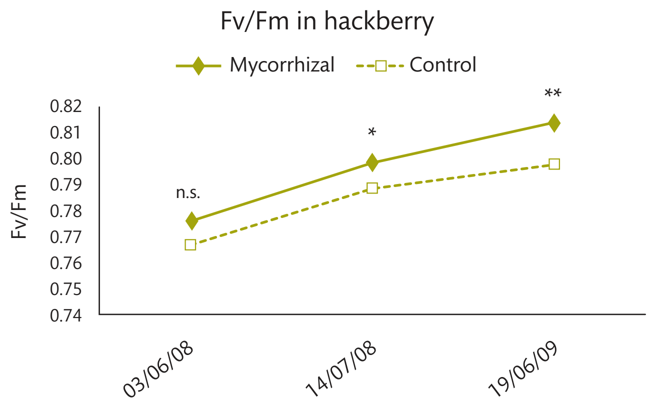



**Figure 6** Maximal quantum yield of photosystem II (Fv/Fm) in inoculated and non-inoculated hackberry planted in a parking lot. * and ** indicate significant differences between mycorrhizal and control trees of the same species at P<0.05 and P<0.01.



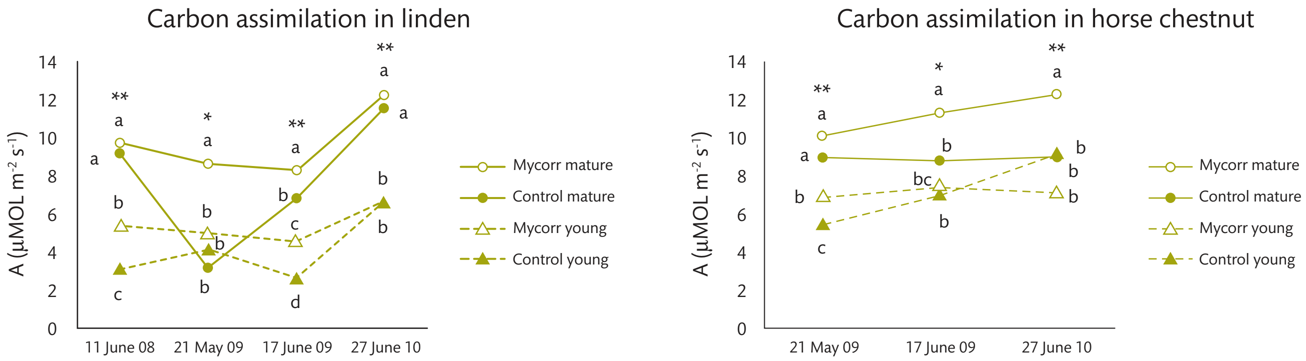

horse chestnut trees. In 2009, shoot growth of linden was higher in inoculated mature trees than in mature untreated trees which, in turn, had higher shoot growth than both inoculated and control young lindens. In horse chestnut, shoot growth was increased by mycorrhizal inoculation in both mature and young trees. As for diameter, shoot growth was higher in young horse chestnut trees than mature ones. Chlorophyll content was affected by mycorrhizal inoculation in mature lindens and young horse chestnuts (Table 7), but was unaffected by mycorrhizal treatments in newly planted linden. Inoculation affected carbon assimilation (A, µmol m$^{-2}$s$^{-1}$) of linden and horse chestnut (Figure 7). When significant differences were found, inoculated plants always had higher A when compared to control plants of the same age.

Table 7 Effects of inoculation with selected mycorrhiza, tree age and their interaction on diameter and shoot growth and chlorophyll content of Tilia and Aesculus planted in an historical garden in the centre of Milan.

| | ΔØ 06/07 (cm) | ΔØ 07/08 (cm) | ΔØ 08/09 (cm) | Shoot growth 2008 (cm) | Shoot growth 2009 (cm) | Chl. content 2008 (SPAD) |
|---|---|---|---|---|---|---|
| ***Tilia*** | | | | | | |
| Mature mycorrhizal | 2.7 a | 1.4 a | 0.8 | 14.5 a | 21.5 a | 52.4 a |
| Mature control | 1.7 a | 0.3 b | 1.3 | 12.1 b | 14.8 b | 47.6 b |
| Young mycorrhizal | 0.6 b | 0.2 b | 0.6 | 9.7 c | 8.6 c | 42.0 c |
| Young control | 0.8 b | 0.2 b | 1.2 | 12.6 b | 7.7 c | 39.8 c |
| P (inoculation) | n.s. | n.s. | n.s. | n.s. | ** | * |
| P (age) | ** | ** | n.s. | ** | ** | ** |
| P (IxA) | n.s. | * | n.s. | * | * | * |
| ***Aesculus*** | | | | | | |
| Mature mycorrhizal | 1.8 a | 0.6 | 0.4 b | 8.8 c | 9.5 c | N.D. |
| Mature control | 1.1 ab | 0.7 | 0.4 b | 5.7 d | 6.1 d | N.D. |
| Young mycorrhizal | 0.6 b | 0.3 | 0.7 ab | 13.7 a | 15.4 a | 43.4 a |
| Young control | 0.9 ab | 0.5 | 1.1 a | 12.1 b | 10.9 b | 40.3 b |
| P (inoculation) | n.s. | n.s. | n.s. | ** | ** | * |
| P (age) | * | n.s. | * | ** | ** | - |
| P (IxA) | n.s. | n.s. | n.s. | n.s. | n.s. | - |

Different letters within the same column and species indicate significant differences between treatments at P<0.05 (*) and P<0.01 (**).

Figure 7 Effects of selected mycorrhiza on carbon assimilation of young and mature *Tilia* (left) and *Aesculus* (right) planted in an historical garden in the centre of Milan. * and ** indicate significant differences between treatments within the same sampling date at P<0.05 and P<0.01.




# Conclusions

Results obtained to date showed that the work of selecting, multiplying and inoculating woody species with site- and species-specific native mycorrhizal fungi can result in greater growth (especially of field-planted trees, as no growth increment was found in container-grown trees) and improved physiology, as can be seen from leaf gas exchange and chlorophyll fluorescence measurements. Time of response was also affected by tree species. For example, *Celtis australis* responded very quickly to mycorrhizal treatment, showing significant differences for shoot growth and chlorophyll content in the first growing season after inoculation, whereas *Fraxinus* required at least two growing seasons before the effect of mycorrhizal inoculation became significant. Tree age also affected success of mycorrhizal inoculum. We tested the same product on newly planted and mature *Tilia* and *Aesculus* growing in a poor, heavily compacted soil and found that symbiosis was more successful on mature trees, compared to newly planted ones. There is evidence that soil compaction limits root growth and activity (Fini and Ferrini, 2007) and reduces mycorrhiza formation (Nadian *et al.*, 1997; Entry *et al.*, 2002). It is possible that roots of young, newly planted trees were more affected by compaction than those of large, established ones. High mortality of fine absorbing roots especially on young linden may explain the reduced effect of mycorrhizal inoculation. The process of selection of native, specific mycorrhizal strains must be implemented by selecting new strains and fungal species for areas which have already been studied and identifying new fungal species/strains in new geographic areas.

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## References

AUGÈ, R.M. (2001). Water relations, drought and vesicular-arbuscular mycorrhizal symbiosis. *Mycorrhiza* **11**, 3–42.

CORDIER, C., GIANINAZZI, S. AND GIANINAZZI-PEARSON, V. (1996). Colonization patterns of root tissues by *Phytophtora nicotianae* var. *parasitica* related to reduced disease in mycorrhiza tomato. *Plant and Soil* **185**, 223–232.

DAVIES, F.T. JR (2000). Benefits and opportunities with mycorrhizal fungi in nursery propagation and production systems. *Combined Proceedings of the International Plant Propagators Society* **50** 482–489.

DE PALMA, L., NOVELLO, V. AND MATTII, G.B. (2004). Scaling up photosynthetic water use efficiency from leaf to whole plant in table grapevine trained to tendone system. *Acta Horticulturae* (ISHS) **664**, 147–154.

DUNABEITIA, M.K., HORMILLA, S., GARCIA-PLAZAOLA, J.I., TXARTERINA, K., ARTECHE, U. AND BECERRIL, J.M. (2004). Differential responses of three fungal species to environmental factors and their role on the mycorrhization of *Pinus radiata* D. Don. *Mycorrhiza* **14**, 11–18.

ENTRY, J.A., RYGIEWICZ, P.T., WATRUD, L.S. AND DONNELLY, P. K. (2002). Influence of adverse soil conditions on the formation and function of arbuscular mycorrhizas. *Advances in Environmental Research* **7**, 123–138.

ESPELETA, J.F., EISSENSTAT, D.M. AND GRAHAM, J.H. (1999). Citrus root responses to localized drying soil: a new approach to studying mycorrhizal effects on the roots of mature trees. *Plant Soil* **206**, 1–10.

FINI, A. AND FERRINI, F. (2007). Influenza dell'ambiente urbano sulla fisiologia e la crescita degli alberi. *Italus Hortus* **14**(1), 9–24.

FINI, A., FERRINI, F., FRANGI, P., AMOROSO, G. AND PIATTI, R. (2009). Withholding irrigation during the establishment phase affected growth and physiology of Norway maple (*Acer platanoides* L) and linden (*Tilia* spp.) *Arboriculture and Urban Forestry* **35**(5), 241–251.

FINI, A., FRANGI, P., AMOROSO, G., PIATTI, R., FAORO, M., BELLASIO, C. AND FERRINI, F. (2011). Effect of controller inoculation with specific mycorrhizal fungi from the urban environment on growth and physiology of containerized shade tree species growing under different water regimes. *Mycorrhiza* **21**, 703–719.

GILMAN, E.F. (2001). Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of *Quercus virginiana*. *Journal of Arboriculture* **27**, 30–38.

GUEHL, J.M. AND GARBAYE, J. (1990). The effects of ectomycorrhizal status on carbon dioxide assimilation capacity, water-use efficiency and response to transplanting in seedlings of *Pseudotsuga menziesii* (Mirb) Franco. *Annals of Forest Science* **21**, 551–563.

GUEHL, J.M., MOUSAIN, D., FALCONNET, G. AND GRUEZ, J. (1990). Growth, carbon dioxide assimilation capacity and water use efficiency of *Pinus pinea* L. seedlings inoculated with different ectomycorrhizal fungi. *Annals of Forest Science* **47**, 91–100.

HABTE, M. (2006). The roles of arbuscular mycorrhizas in plant and soil health. *In:* Uphoff *et al.* (ed.) *Biological approaches to sustainable soil systems*. Taylor & Francis, Boca Raton, London.

JONER, E.J., BRIONES, R. AND LEYVAL, C. (2000). Metal binding capacity of arbuscular mycorrhiza mycelium. *Plant and Soil* **226**, 227–234.

KAYA, C., HIGGS, D., KIRNAT, H. AND TAS, I. (2003). Mycorrhizal colonization improves fruit yield and water use efficiency in watermelon (*Citrus lantanus* Thumb) grown under well-watered and water-stressed conditions. *Plant and Soil* **253**, 287–292.

KOSKE, R.E. AND GEMMA, J.N. (1989). A modified procedure for staining roots to detect VA mycorrhizas. *Mycological Research* **92**, 486–505.

LUH, F.C.W., GRABOSKY, J.C. AND BASSUK, N.L. (2002). Using the SPAD 502 meter to assess chlorophyll and nitrogen content of benjamin fig and cottonwood leaves. *HortTechnology* **12**(4), 682–686.

MCGONIGLE, T.P., MILLER, M.H., EVANS, D.G., FAIRCHILD, G.L. AND SWAN, J.A. (1990). A new method which gives and objective measurement of colonization of roots by vescicular-arbuscular mycorrhizal fungi. *New Phytologist* **115**, 495–501.

MANCUSO, S. AND RINALDELLI, E. (1996). Responses of young mycorrhizal and non-mycorrhizal plants of olive tree (*Olea europaea* L.) to saline conditions. II. Dynamics of electrical impedance parameters of shoots and leaves. *Advances in Horticultural Science* **10**, 135–145.

MATSUBARA, Y., OHBA, N. AND FUKUI, H. (2001). Effect of arbuscular mycorrhizal infection on the incidence of *Fusarium* root-rot in asparagus seedlings. *Journal of the Japanese Society for Horticultural Science* **70**, 202–206.

NADIAN, H., SMITH, S.E., ALSTON, A.M. AND MURRAY, R.S. (1997). Effects of soil compaction on plant growth, phosphorus uptake and morphological characteristics of vescicular-arbuscular mycorrhizal colonization of *Trifolium subterraneum*. *New Phytologist* **135**, 303–311.

NEWTON, A.C. AND PIGOTT, C.D. (1991). Mineral nutrition and mycorrhizal infection of seedling oak and birch. II. The effects of fertilizers on growth, mineral nutrition and ectomycorrhizal infection. *New Phytologist* **117**, 45–52.

PERCIVAL, G. (2005). The use of chlorophyll fluorescence to identify chemical and environmental stresses in leaf tissue of three oak (*Quercus*) species. *Journal of Arboriculture* **31**(5), 215–227.

PERCIVAL, G.C., KEARY, I.P. AND NOVISS, K. (2008). The potential of a chlorophyll SPAD meter to quantify foliar nutrient stress in foliar tissue of Sycamore (*Acer pseudoplatanus*), English oak (*Quercus robur*) and European beech (*Fagus sylvatica*). *Arboriculture and Urban Forestry* **34**(2), 89–100.

RINALDELLI, E. AND MANCUSO, S. (1996). Responses of young mycorrhizal and non-mycorrhizal plants of olive tree (*Olea europaea* L.) to saline conditions. I. Short-term electrophysiological and long-term vegetative salt effects. *Advances in Horticultural Science* **10**, 126–134.

SAMMONS, J.D. AND STRUVE, D.K. (2008). Monitoring effective container capacity: a method for reducing over-irrigation in container production systems. *Journal of Environmental Horticulture* **26**(1), 19–23.

SMITH, S.E. AND READ, D.J. (1997). *Mycorrhizal symbiosis*. Academic Press, London, 605 pp.

THYGESEN, K., LARSEN, J. AND BODKER, L. (2004). Arbuscular mycorrhizal fungi reduce development of pea root-rot caused by *Aphanomyces euteiches* using oospores as pathogen inoculum. *European Journal of Plant Pathology* **110**, 419–441.

TIMONEN, S. AND KAUPPINEN, P. (2008). Mycorrhizal colonization patterns of *Tilia* trees in street, nursery and forest habitats in southern Finland. *Urban Forestry and Urban Greening* **7**, 265–276.

WILLITS, D. AND PEET, M. (2001). Using chlorophyll fluorescence to model leaf photosynthesis in greenhouse pepper and tomato. *Acta Horticulturae* **507**, 311–315.

WISEMAN, P.E. AND WELLS, C.E. (2009). Arbuscular mycorrhizal inoculation affects root development of *Acer* and *Magnolia* species. *Journal of Environmental. Horticulture* **27**(1), 70–79.

YAO, M., LI, X., FENG, G. AND CHRISTIE, P. (2001). Mobilization of sparingly soluble inorganic phosphates by the external mycelium of an arbuscular mycorrhizal fungus. *Plant Soil* **230**, 279–285.

# Fundamentals of tree establishment: a review

*'The best time to plant a tree was twenty years ago.*
*The second best time is now.'*
Anonymous

## Abstract

Mortality of landscape trees regularly reaches 30% in the first year after planting. This review aims to highlight the fundamental factors and procedures critical to tree establishment. If these are fully considered and acted upon, significant reductions in transplant losses can be expected. The principal elements essential for successful tree establishment have been identified as tree ecophysiology; rooting environment; plant quality and planting and post-planting. These are presented in a model which helps describes the multiplicity of factors involved in successful establishment and, importantly, their interrelated nature. An understanding of how transplant survival can be markedly influenced by these factors is paramount and failure to consider any one element may lead to tree mortality. Attention is also given to practices which have been demonstrated to greatly enhance tree vitality during the establishment phase.

## The challenge of tree establishment

**Keywords:**

tree establishment, tree planting

Trees planted into urban landscapes such as streets, recreational areas and car parks provide important benefits to urban populations. These include absorption of pollutants, reduction of traffic noise, windbreaks and shelter, as well as reduction of radiation and solar heat gain through shading and evapotranspiration (NUFU, 2005; Hiemstra *et al.*, 2008; Forest Research, 2010). Trees also provide shape, scale, form and seasonal changes to the landscape. However, as early as the 1980s failure rates for amenity tree planting were commonly recorded as 30%, but failure rates of 70% were reached with disturbing regularity during the first growing season (Gilbertson and Bradshaw, 1985, 1990). Further research in the late 1990s and 2008 highlighted similar failure rates (Johnston and Rushton, 1999; Britt and Johnston, 2008). In view of the resource life-history an amenity tree has in terms of irrigation, fertilisers (if applied), transport costs, planting materials, labour, etc., in addition to the actual loss of the tree, the persistence of these failure rates can no longer be accepted. Such significant losses also challenge us to consider why, over a 30 year period, mortality rates of 30–50% are still commonplace during the first year after planting.

A number of reasons exist. While it is appreciated by professionals involved in urban tree management that trees are planted into suboptimal conditions for growth, the extent and diversity of stresses urban environments impose is frequently under-estimated. Table 1 identifies abiotic stresses which may affect urban trees.

Transplant survival is influenced by the range of factors outlined in Figure 1. *Tree ecophysiology* considers the genetic potential of trees to establish in a given environment and species characteristics which may reduce the impact of a particular stress. High *plant quality* is an essential foundation for any planting project. *Planting and post-planting* practices are fundamental to establishment success. The *rooting environment* is critical in ensuring future resource availability and anchorage. Failure to give full consideration to any one of these factors increases the likelihood of a high mortality rate in a tree planting scheme.

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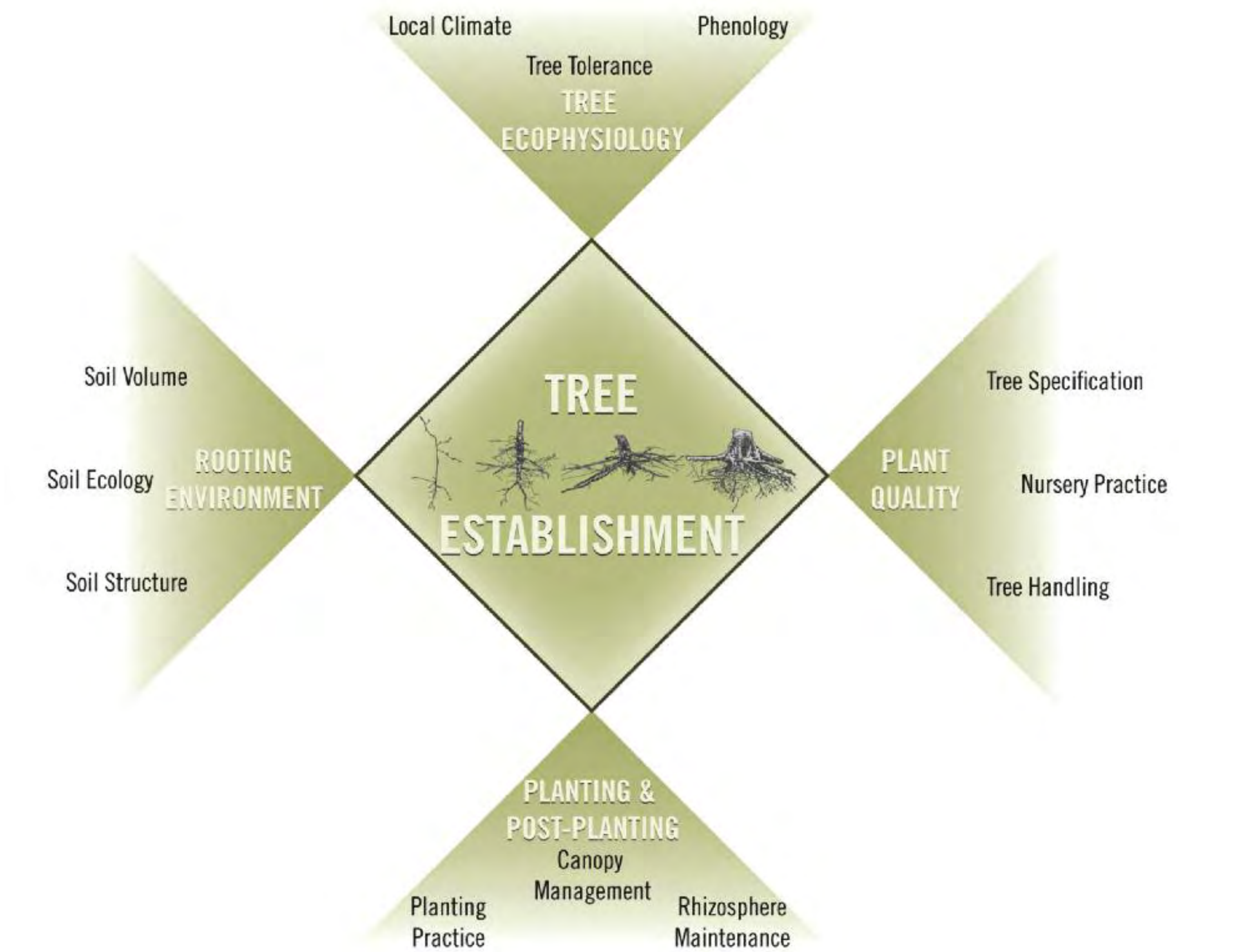
Table 1 Potential abiotic or non-living stresses affecting urban trees.

| Abiotic stresses | |
|---|---|
| High irradiance (photoinhibition, photooxidation) | Herbicides, pesticides, fungicides |
| Heat (increased temperature) | Air pollutants ($SO_2$, NO, $NO_2$, $NO_x$) |
| Low temperature (chilling, frost) | Ozone ($O_3$) and photochemical smog |
| Drought (desiccation problems) | Formation of highly reactive oxygen species ($^1O_2$, radicals, $O_2^-$ and OH, $H_2O_2$) |
| Natural mineral deficiency | Photooxidants (peroxyacylnitrates) |
| Waterlogging (root deoxygenation) | Acid rain, acid fog and acid morning dew |
| Competition for light, water, nutrients | Acid pH of soil and water |
| Excess de-icing salts (Na, Cl) | Over supply of nitrogen (dry and wet $NO^3$ deposits) |
| Heavy metals | Increased UV-radiation |
| Increased $CO_2$ levels (global climate change) | |

Figure 1 A model of the key factors involved in successful tree establishment




## Transplant stress

The common observation of slow growth, tree decline and/or death following transplanting is characterised as transplant stress. The marked reduction in root:shoot ratio due to the lifting process in the nursery results in a severe limitation to resource capture. Newly transplanted trees are, therefore, incapable of meeting the water and nutrient demands of the canopy. Consequently, the efficient return to a pre-transplant root:shoot ratio is essential for survival and establishment of transplanted trees (Davies *et al.*, 2002).

# Tree ecophysiology

Each tree species has an inherent capacity for growth. This relates to a complex array of morphological, anatomical and physiological attributes. Most obviously, these influence tolerance to climate (and microclimate), but a number of characteristics have been observed to promote tolerance to transplanting.

## Local climate

The significance of climatic factors on tree performance is broadly appreciated by those involved in tree management. When, however, it is necessary to make decisions on tree selection for a given site it is soon apparent that robust data on climatic suitability is poorly developed or non-existent. Inherently poor climatic fit in terms of growing season temperature and solar radiation can markedly influence the performance of many species that are of continental European-Asian or North American distribution, which perform satisfactorily in South East England but struggle within a UK northern climate (Percival and Hitchmough, 1995). Problems can be exacerbated within an urban landscape where several microclimates (a local atmospheric zone where the climate differs from the surrounding area) may exist within very short distances. Microclimates exist, for example, near bodies of water which may cool the local atmosphere, or in heavily urban areas where brick, concrete and asphalt absorb the sun's energy and radiate that heat to the ambient air, resulting in an urban heat island. South-facing slopes are exposed to more direct sunlight than opposite slopes and are, therefore, warmer for longer. Tall buildings create their own microclimate, both by overshadowing large areas and by channelling strong winds to ground level. Local climate knowledge is important as the biological events of trees (flowering, seed set, bud burst, etc) are controlled by environmental triggers. Disruption to these triggers can be manifest for example by cherries under artificial street lights flowering in winter due to a disrupted photoperiod (Harris *et al.*, 2004). Consideration of the precise environmental conditions in which the tree will be located is an essential criterion for tree selection.

## Tree tolerance

Tolerance to transplanting has been shown to vary widely between different genera with *Populus*, *Salix* and *Alnus* widely regarded as transplant tolerant while *Fagus*, *Juglans* and *Aesculus* are transplant sensitive (Watson and Himelick, 1997). Reasons for these differences are complex and have never been fully elucidated, although some of the salient factors have been identified.

Soil moisture and temperature are most influential in determining the periodicity of root growth but in reality multiple factors are involved (Eissenstat and Yanai, 2002). Ease of transplanting has been linked with root morphology and the rate of root regeneration. For example, root regeneration rates of green ash began at 9 (root tip elongation) and 17 (formation of adventitious roots) days after planting, while in red oak such responses were not recorded until days 24 and 49 (Arnold, 1987). Species with fibrous root systems that have significantly more profusely branched root systems are suggested to be easier to transplant than species with coarse root systems (Struve, 1990). Although variation between species will exist, at least six or more lateral roots should be present when planting as lower numbers of lateral roots are associated with a decrease in survival rates (Struve, 1990). Likewise, trees that possess physiological adaptations to waterlogging such as the formation of aerenchyma (intercellular gas-filled spaces) in the root cortex, the development of adventitious roots and enlarged lenticels, anaerobic carbohydrate catabolism and oxidisation of the rhizosphere tend to have higher survival and establishment rates than species which do not possess these characteristics. Trees with specific anatomical features associated with drought (thicker waxy cuticle, presence of hairs on the leaf surface, sunken stomata located on the underside of the leaves) also tend to be associated with higher transplant success, as drought-induced water deficits are regarded as one of the major causes of failure of newly planted trees (Watson and Himelick, 1997; Pallardy, 2008).

## Phenology

Phenology relates to the recurring patterns of plant development which occur in response to climate and environment (Larcher, 2003). Consideration of the tree development stage is important for successful tree establishment. Trees planted early in the dormant season (November-December) tend to survive and have higher survival rates than trees planted later in the growing season. However, there may be some advantage to spring planting in some species (Richardson-Calfee *et al.*, 2004). The importance of high concentrations of carbohydrate reserves within root tissue for survival and growth following transplanting are well recognised. Root growth is an energy-consuming process occurring at the expense of available carbohydrate reserves (Martinez-Trinidad *et al.*, 2009c). During cold storage carbohydrate reserves accumulated during the previous growing season are depleted due to respiration. Consequently, longer storage periods equate to less accumulated carbohydrate reserves. This may impact on canopy expansion in spring and a concomitant increase in transplant mortality (Lindqvist and Asp, 2002). Total tree energy levels can decrease by 40 to 70% between bud-break and total canopy development depending on species (Struve, 1990). Storage compounds become more important to establishment success as planting conditions worsen. Reduced photosynthetic leaf tissue during bud-burst and initial leaf expansion in deciduous trees means energy for these processes comes mainly at the expense of reserve carbohydrates (Martinez-Trinidad *et al.*, 2009a, 2009b).

# Plant quality

Without exception, healthy landscape trees are derived from high quality nursery stock. Ensuring high quality trees are available for planting is essential if successful establishment is to take place. While mechanisms such as tree specification can play important roles in securing good quality stock, it is vital that tree handling procedures during transport and on-site adequately protect plant material from damage.

## Tree specification

Considerable variation exists across tree nurseries so purchasers of trees should learn to evaluate nurseries and if necessary discriminate against those which fail to consistently deliver high quality stock. Some authors (Clark, 2003; Sellmer and Kuhns, 2007) advocate the use of tree specifications which provide robust and precise guidelines detailing tree characteristics required at the time of purchase (Table 2).

## Nursery practice

A number of nursery production practices can influence the establishment of trees. Perhaps of greatest significance is the extent to which the root system can be diminished during transplanting; Watson and Himelick (1982) estimated that up to 98% of the roots may be left at the nursery. This leaves an inadequate root area for resource acquisition and is the determining factor in many transplant failures. Maximising the volume of roots taken with the tree at time of transplanting is critical to successful establishment. Practices and methods which seek to achieve this are essential in producing high quality amenity trees.

Root pruning can, if done routinely, promote and maintain a compact fibrous root system (Watson and Sydnor, 1987). This is generally observed to improve transplant survival (Gilman *et al.*, 2002) but others have observed little effect on growth as a result of root pruning (Harris and Fanelli, 1998).

Seedlings grown in containers for too long can develop circling root defects which will persist in form to such an extent that they can girdle the tree causing instability and restriction in the translocation of materials (Watson and Himelick, 1997). Formation of girdling roots is also associated with stimulation of lateral roots in response to a main root severance (Watson *et al.*, 1990). Pot design which facilitates the air pruning of lateral roots (e.g. Air-Pots™) can significantly reduce root defects and subsequent problems of root circling (Single and Single, 2010). White fabric containers (e.g. Barcham Light Pots™) which allow the transmission of some light through have also been shown to reduce root circling (Grimshaw and Bayton, 2010). Where trees are grown in containers, it is good practice to identify a

Table 2 Important tree specification criteria.

| Tree specification criteria | |
|---|---|
| **Above ground** | **Below ground** |
| Specimen true to species or variety type | High root ball occupancy |
| Graft compatibility (if appropriate) | Diversity in rooting direction |
| Healthy with good vitality[1] | Good root division |
| Free from pests, disease or abiotic stress | Extensive fibrous root system |
| Free from injury | Free from root defects (e.g. circling roots) |
| Self-supporting with good stem taper | Free from pests, disease or abiotic stress |
| Stem-branch transition height | |
| Sound branch attachment and structure | |
| Good pruning wound occlusion | |
| Canopy symmetry | |

[1] *Visual assessment could be supported with chlorophyll fluorescence data*

'shelf-life' to prevent landscape trees from inheriting root defects from tree nurseries.

High density spacing between plants in the nursery can have two potential impacts on tree establishment. First, stem taper is diminished when trees are grown in very close stands; this impacts the future ability of the tree to be self-supporting. Secondly, shading becomes more significant, which reduces the level of photosynthesis and its products. Losses in carbon available for growth and storage as a result of this may have an impact on transplant success (Sellmer and Kuhns, 2007).

Shoot or canopy pruning can, if done appropriately, enhance the future structure of the tree by reducing conflicts between branches, removing branches with poor attachments and encouraging crown symmetry. However, poor practice may destroy natural form, excessively reduce leaf area and extensively wound stems. Working with growers to develop best practice is of strategic importance in enhancing tree establishment. The collaboration and cooperation across sectors involved in the specification, production and planting of trees should be encouraged by all stakeholders.

### Tree handling

Care should be taken when trees are transported from the nursery to the planting site. Use a covered vehicle that protects the roots from wind and temperature extremes. Trees should be watered prior to shipping and ideally the root ball checked for moisture at arrival using a soil moisture probe. On site material should be maintained under shade and irrigated at least twice daily if temperatures are ≥24°C. Plants should be healed-in if required and protected from extremes in temperature (frost, etc.). Ideally, handle trees by the root ball using straps or powered equipment rather than lifting using branches or the trunk. The trunk should also be wrapped during shipping and the planting process for protection. Exposed roots desiccate very rapidly in air and it is imperative that this is not allowed to happen at any stage of handling. Failure to do so often results in tree mortality.

## Rooting environment

In one of the earliest arboricultural texts, Solotaroff (1911) states 'a great deal, if not all of the success in tree growing, depends upon the nature and the preparation of the soil'. This observation has, over time, been proven to be true.

Soil provides a vital medium for tree growth and development through the provision of water and mineral nutrients and by acting as a substrate for plant anchorage (Kozlowski *et al*., 1991). While soil is extremely heterogeneous, healthy natural soils are associated with a balance of solid material, air and water in a typical volumetric composition. Rock particles (mineral matter) make up 45%, organic matter 5%, while air and water each occupy 20–30% of the soil volume (Brady and Weil, 2008). The solid materials host a labyrinth of pore spaces which in turn provide aeration and hold water within the soil profile. Soil texture, soil structure and soil biota are further characteristics which control soil functions vital for tree growth.

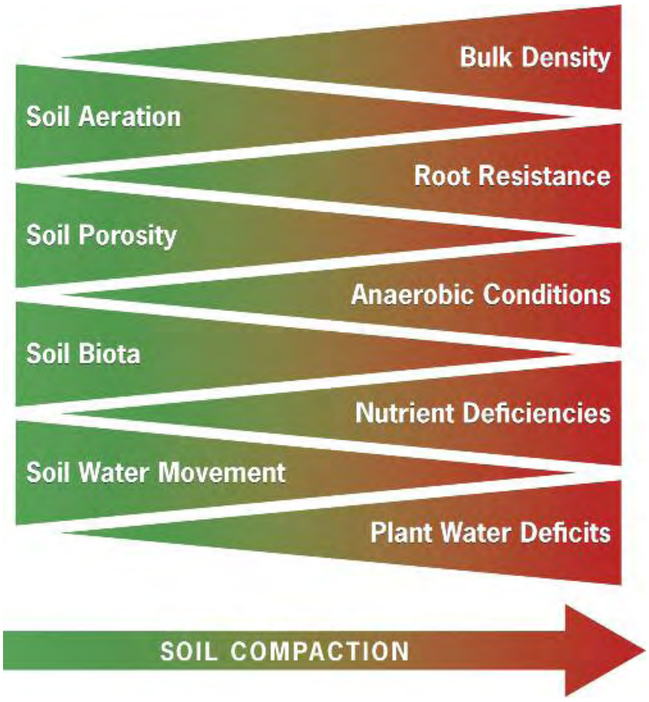
Soils in urban landscapes are generally thought of as highly disturbed, highly variable and of low fertility (Craul, 1999). However, Pouyat *et al*. (2010) provide evidence that observations of entire landscapes have shown that soils which are largely undisturbed or of high fertility may also be found in urban areas. High variability in nitrogen availability in urban soils was also found by Scharenbroch and Lloyd (2006). Such diversity, therefore, requires professionals and practitioners involved with tree establishment to have a high level of knowledge relating to tree development under different prevailing soil conditions.

The extent of soil compaction has particular significance for the process of tree establishment because it acts on a range of criteria which may limit tree vitality (Figure 2). As soil is compacted, physical resistance to roots is increased; soil aggregates break down and pore space is diminished. This reduces soil aeration, detrimentally affecting biological respiration of roots and soil biota, which in turn impacts nutrient cycling and availability. Modification of soil structure also changes hydraulic properties and significantly slows water movement through the soil presenting both water deficits and waterlogging as potential problems (Kozlowski, 1999).

It is generally accepted that most roots are unable to penetrate moist soils of a bulk density greater than 1.4–1.6 $g\,cm^{-3}$ in fine textured soils and 1.75 $g\,cm^{-3}$ in more coarsely textured soils although this will be reduced in drier soils and variation does exist across species (Kozlowski, 1999; Brady and Weil, 2008).

Soil compaction beyond these thresholds frequently exists in urban situations as a result of vehicular and pedestrian traffic but may also be necessary for engineering purposes. Where such densities exist, the soil volume available for tree root growth is significantly reduced. This has led a number of authors to suggest that available soil volume is the most limiting factor in the growth of urban trees (Kopinga, 1991; Craul, 1992; Lindsey and Bassuk, 1992; Grabosky and

Figure 2 Soil characteristics modified by soil compaction.




Bassuk, 1995). A number of approaches have been explored to calculate the soil volume a tree requires; these are generally based on either nutritional or water requirements. Lindsey and Bassuk (1991) developed a calculation based on potential crown projection, where this was equivalent to the area under the tree's drip line; leaf area index (LAI) and local meteorological conditions to determine daily whole tree water use. This is then integrated to the known water holding capacity of the soil in order to determine the volume of soil required to meet the water needs of a tree. As a general estimate 0.06 $m^3$ of soil is recommended for every 0.09 $m^2$ of crown projection. While this approach is helpful, functional diversity across tree water use strategies, heterogeneity in soil moisture release characteristics and peculiarities of local microclimate dictate that an assessment of genuine tree soil volume requirements are highly complex. Despite the potential uncertainty surrounding absolute soil requirements, a resounding message from various soil volume calculations is that soil volumes frequently found in urban environments are inadequate.

In recognition of the need to enhance soil volumes artificial substrates known as 'structural soils' (e.g. Amsterdam tree soil; Cornell University structural soil; Stalite) have been designed to take limited engineering loads while maintaining a structure which still facilitates root development (Couenberg, 1994; Grabosky and Bassuk, 1995; Kristoffersen, 1998). This approach undoubtedly enhances available rooting volumes but, as a result of the high sand and stone fraction in these soils, persistent retention of water and nutrients has been cited as a potential problem (Trowbridge and Bassuk, 2004). Smiley *et al*. (2006) compared growth parameters on trees established in structural and non-compacted soil and surrounded by pavement. Trees in the non-compacted soil treatment out-performed structural and compacted soils in almost every parameter measured. This underscores the importance of compaction in urban soils and highlights the limitations of some structural soils in providing a suitable substrate for tree establishment.

Recently, structural cells (e.g. SilvaCell® and StrataCell™) have been developed to help enhance the soil volumes available to tree roots. These cells have a rigid framework capable of bearing loads encountered in urban environments and voids designed to contain high quality soil. As a result, compaction within the rooting environment is prevented and soil conditions which promote tree vitality can be maintained (Urban, 2008). However, long-term studies which assess the value of these systems are needed to provide robust evidence of their value: none currently exist.

## Planting and post-planting

Frequently, the right tree has been selected for the right place, a high quality plant has been secure from the nursery and the root environment is capable of providing resources for tree development, but deficient planting practices and inadequate post-planting aftercare cause tree failure. Education clearly has a role, but good practice should be enforced through robust management and the extensive use of planting specifications which give precise expectations of all planting and post-planting operations. Practitioners can then be accountable to this specification and audits may be carried out to monitor work standards.

### Planting practice

Several best management practices regarding tree planting can be found in the established arboricultural literature (e.g. Watson and Himelick 1997; Harris *et al*., 2004). While some challenges in tree planting are yet to be fully resolved, the fundamental practices are apparent.

i. *Assess the roots or root ball for potential defects*; the upper roots must not be more than a few centimetres below the soil surface; the stem flare must be visible; and roots which circle over one third of the root ball should be removed.
ii. *Prepare the planting site*; an area two to three times the diameter of the root ball should be decompacted; and the planting hole itself should be no deeper than the existing

root ball or the root-stem transition. In urban sites the preparation of the planting site may include additional infrastructure such as structural cells, irrigation and aeration systems and root management systems.

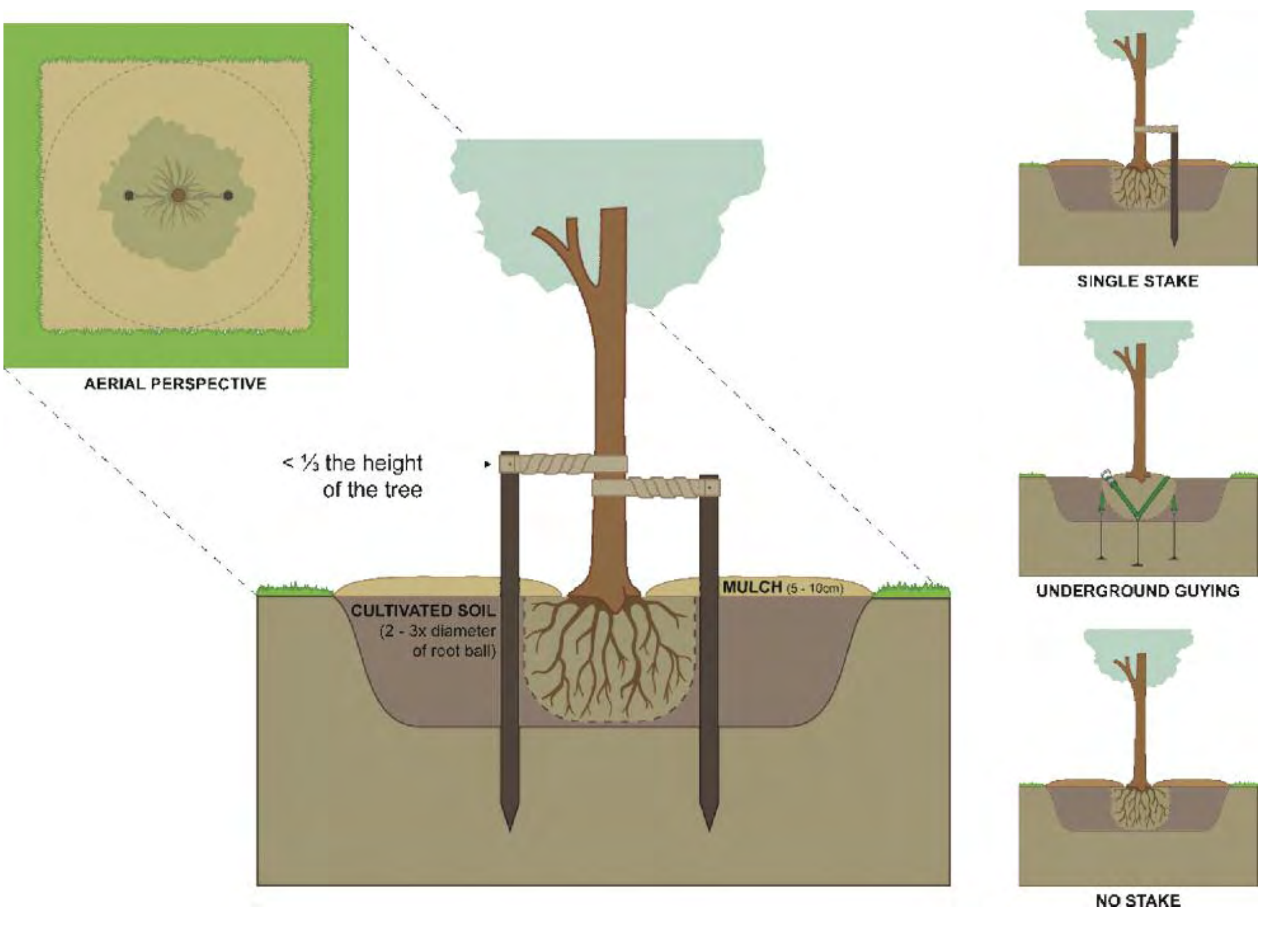
iii. *Plant the tree* so that the root ball or root-stem transition is level with the existing host soil. Add backfill gradually ensuring the tree is held upright and be careful not to cause excessive compaction when firming in. Soil removed from the hole makes the best backfill. Water the root ball and planting area immediately after planting. Support systems of trees are considered below (Figure 3).

One of the most common errors in tree planting is that the root ball is either planted too deep or too high, both of which can cause serious problems. Planting trees 7–8 cm below the root ball, for example, resulted in 30–50% death rates of several different species representing a wide range of different genera (Arnold *et al*., 2007). In fact, Arnold *et al*. (2007) suggest that in some species planting 7–8 cm above grade may confer some advantage to establishment. It is also of critical importance to ensure that the roots are not allowed to desiccate at any stage during handling or planting. This causes irreversible damage to the root system and greatly increases the likelihood of transplant failure.

## Tree maintenance

A number of approaches have been advocated to physically support trees. Regardless of technique, the support system should allow stem and canopy movement so that reaction wood develops the stem taper and root growth is stimulated. Support systems which restrict canopy and stem movement also restrict these processes from occurring. Best management practices, therefore, recommend the support as low as possible (Appleton *et al*., 2008). Tree ties should seek to spread the load of support on the stem with a wide band (usually hessian or rubber); this must also facilitate radial expansion of the stem. Alternatively, below-ground root anchor systems may be used: these allow full above-ground movement and help give the impression of an established tree. Furthermore, in pedestrian areas trip hazards are avoided. Do not anchor trees too high on the trunk and avoid securing guides in narrow crotch angles of branches. Prevent bark abrasion by using rubber straps, pads, hessian ties or springs with supports or stakes. Remove all forms of support after new root growth adequately stabilises the tree. This can vary by tree species, size, soil type, etc. As a general guide it should be acceptable to remove all support within two years of planting.

**Figure 3** Planting and staking techniques.



Formative pruning can help achieve good branch structure and reduce future hazards (Harris *et al*., 2004). It may be necessary to remove broken branches (from handling procedures) and occasional branches which show serious conflict with others. However, it is essential that as much of the canopy remain intact as possible as a reduction in leaf area directly impacts carbon gain and, therefore, the energy resources available for root development. Any pruning should follow the natural target pruning method outlined in standard arboricultural texts (Gilman, 2002; Brown and Kirkham, 2004; Harris *et al*., 2004).

## Rhizosphere maintenance

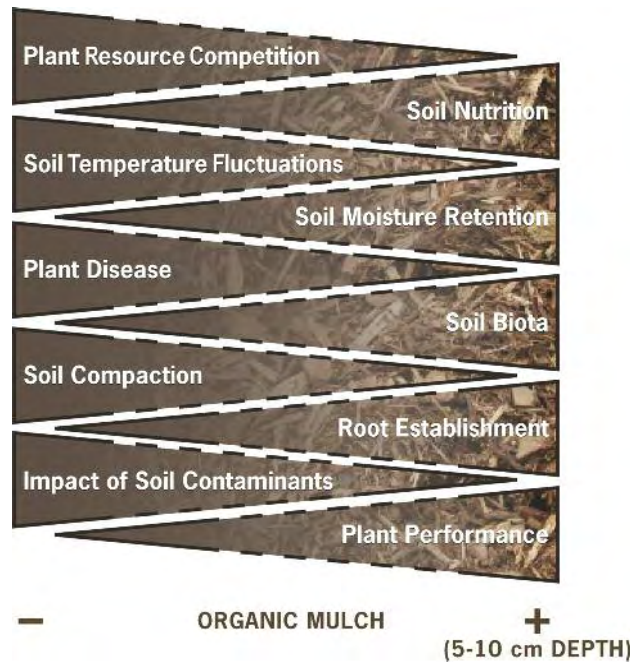
The rhizosphere is the region of soil in intimate contact with the roots of a plant and its health is critical to plant performance. It contains a complex array of plant-associated communities of organisms vital for soil health (Buée *et al*., 2009). While it is difficult to directly influence the actual rhizosphere, interventions to promote soil ecology and good soil structure will promote rhizosphere health and concomitantly improve tree performance. It is essential that soil health is on the agenda of those seeking to establish trees in the urban environment.

The use of various soil amendments to include auxins, mycorrhiza, biostimulants, sugars and hydrogels have been advocated as a means of reducing transplant losses. However, data from several independent research trials demonstrate widely conflicting opinions as to their usefulness. While the potential of these amendments is appreciated, further research is required before definitive conclusions can be reached regarding their use (Smiley *et al*., 1997; Percival and Fraser, 2005; Barnes and Percival, 2006).

Mulching is an essential component to reduce transplant losses and should always be undertaken. Benefits of mulches include minimising fluctuations of soil temperature and soil moisture; weed suppression; soil nutritional enrichment; the prevention of soil erosion from heavy rains; regulation of pH and cation exchange capacity (CEC); pathogen suppression; increasing soil microbial activity and improving aeration (Figure 4). In addition mulches can prevent mower and strimmer damage to the tree trunk and act as a buffer in preventing excess de-icing salts from percolating into the soil to around the root zone (Chalker-Scott, 2007). Landscape mulches include both inorganic (e.g. crushed stone, crushed brick, gravel, polyethylene films) and organic mulches (shredded branches and leaves, softwood and hardwood tree bark, wood chips, sawdust, pine straw, recycled pallets and mixes of the above). The use of organic rather than inorganic mulches in urban landscapes is suggested for improved root growth of establishing trees (Chalker-Scott, 2007). Recent studies have focused on the effectiveness of organic mulches derived solely from a single tree species (defined as a 'pure' mulch). Results demonstrated that pure mulches can have a substantial effect on tree survival rate and growth at the end of the growing season and are an area worthy of future research (Percival *et al*., 2009).

Mulch should be between 5 and 10 cm thick and applied from the drip line to the trunk. If this is not practical, minimum mulch circle radii should be 0.3 m for small trees, 1 m for medium trees and 3 m for large trees. Mulch should not be placed against the trunk as this will retain moisture against the trunk that may result in disease.

Figure 4 The multiple biological effects of organic mulching. Dashed lines indicate that it is unlikely to be a linear transition.




Water deficits affect almost every aspect of tree growth and development (Pallardy, 2008). Tree water deficits are nearly always associated with periodic drought but the significant damage to tree root systems and limited soil volumes, often observed on urban planting sites, frequently contribute to serious tree water deficits. Transpirational demands cannot be met as a result of root loss during transplanting or restricted access to soil water. Post-planting irrigation has been cited as the most important maintenance practice (Watson and Himelick, 1997) and critical to tree establishment. Water deficits are regarded as the major causes of failure of newly planted trees resulting in loss of leaf turgor, stomatal closure, decreased photosynthesis and reduced metabolic functions. In areas where newly planted trees are not irrigated initial establishment relies heavily on precipitation. If the transplant does not receive sufficient precipitation during the period of new root regeneration, its internal water deficits increase considerably due to excessive water transpiration and non-absorption of water from the soil. Determining when to irrigate, or scheduling, irrigation should integrate knowledge of meteorological data, soil moisture release characteristics and tree species response to water deficit.

If irrigation seeks to replace evapotranspiration then calculations based on standard formulas have been applied for a wide range of crops (Allen *et al.*, 1999); however, the diversity of species, planting densities and microclimate have led Costello *et al.* (2000) to develop a modified approach for landscape plantings. While this has significant merit at the landscape scale it cannot take account of the significant heterogeneity in urban soils and relies on the availability of meteorological data. Assessment of soil moisture has greater value on individual sites as it can relate to the specific conditions experienced by vegetation and takes account of local soil hydrology.

The most important soil characteristic to evaluate is the matric potential (soil water potential): usually this is assessed using a tensiometer. Each soil has an individual moisture release characteristic which is determined by factors such as texture, parent material and organic matter content. This results in significant differences in soil water availability even when soil volumetric content is consistent across different soil types. For example, a sandy soil with a volumetric water content of 5% will contain water which is readily available to the tree, whereas, a loam-based soil at the equivalent volumetric content will contain no available water. Assessing the volumetric water content is therefore of limited value unless the corresponding matric potential of the soil is known (Kramer and Boyer, 1995).

A further factor is the variation in the ability of a particular species to withstand periods of water shortage and flooding. Niinemets and Valladares (2006) provide a tolerance index which may be used to assist the assessment of relative species' drought and waterlogging tolerance. However, it should be noted that variation in drought tolerance is also observed in different cultivars of the same species (Fini *et al.*, 2009).

Post-planting irrigation can aid establishment but variation in irrigation frequency had a greater impact on the establishment of live oak (*Quercus virginiana*) and red maple (*Acer rubrum*) (Gilman *et al.*, 1998, 2003) than irrigation volume. However, caution is needed when applying findings of research from contrasting climates, species drought tolerance and soil types as irrigation requirements may differ greatly.

Prior to large-scale plantings soil analysis should always be undertaken to take into consideration pH, macro and micronutrient deficiencies, heavy metal content and salinity. Planting trees into soils with, for example, an inappropriate pH or elevated heavy metal content will only compound transplant losses (Percival, 2007). According to several researchers transplant growth can be regulated to a large extent by nutrient levels present in a fertiliser with nitrogen (N) identified as the macronutrient having the greatest influence (Zandstra and Liptay, 1999). However, the effects of N fertilisers upon survival of trees post-planting are conflicting (see Percival and Barnes, 2007, for a full review). Proliferation of tree root systems in a moist N-rich environment has been demonstrated and work elsewhere concluded that fine root turnover of trees increased exponentially with soil N availability (Gilbertson *et al.*, 1985). Researchers at the Morton Arboretum in the USA concluded that only application of granular N significantly increased root density of honeylocust (*Gleditsia triacanthos* var. inermis) and pin oak (*Quercus palustris*) compared to granular potassium and phosphorus fertilizers (Watson, 1994). Contrary to this, other researchers studying the influence of N fertilisers on alterations to root:shoot ratios demonstrated little or no impact on root stimulation (Day and Harris, 2007). These results are consistent with those obtained from other studies using *Hopea odorata* and *Mimusops elengi*, *Pseudoacacia menziesii*, *Liriodendron tulipifera*, *Acer rubrum*, *Tilia cordata* and *Azadirachta excelsa* as test species (Zainudin *et al.*, 2003; Day and Harris, 2007). Regarding use of fertilisers as a means of reducing transplant stress the conclusions reached by most researchers are:

i. Prior to large-scale plantings, cores of soil should be sent to a reputable laboratory for soil nutrient analysis and any nutrient deficiencies remediated with appropriate fertilisation.

ii. Trees planted in a well-drained, aerated soil which contains an adequate supply of nutrients do not need fertilising.

iii. In general, applications of fertilisers result in more balanced growth vital for plants growing in harsh urban environments where competition for water and nutrients is high and/or resource availability is low.

Where the bulk density of the soil is demonstrated to be limiting to tree development, decompaction of the rooting environment has considerable value regardless of tree age.

While a variety of approaches are available to 'decompact', the value of some equipment has been questioned (Smiley *et al*., 1990; Smiley, 1994; Hascher and Wells, 2007). It is now clear that only those approaches which result in a significant and widespread reduction in soil bulk density throughout the rooting volume have appreciable merit. High pressure pneumatic soil excavation tools (e.g. Air Spade®, Supersonic Air Knife, Soil Pick©) have been demonstrated to achieve this and are capable of cultivating the soil to a depth of 25–30 cm using compressed air to excavate soil with minimal disturbance or damage to tree roots (Felix, 2004). Fite *et al*. (2009) found this approach to be particularly valuable when combined with a nutritional amendment in a technique known as Root Invigoration™. Since there is so little damage, larger areas can be excavated, which greatly expand the available area for root growth and development (Smiley, 1999). However, concern has been raised regarding the potential damage of applying compressed air to the soil surface and root system (Kosola *et al*., 2007). Further research in this area is ongoing but, at present, it seems likely that the long-term benefits of soil decompaction outweigh the minor damage to the fine root system.

## Conclusions

This paper identifies a framework which, if fully evaluated, will greatly enhance tree establishment rates. Landscape professionals should consider *tree ecophysiology*, the *rooting environment*, *plant quality* and *planting and post-planting practice* in every new tree planting scheme. Empirical evidence, in addition to academic literature, suggests that neglecting to consider any of these fundamental factors will result in the unacceptable failure rates observed in recent decades. The integration and application of current best practice in each of these areas will greatly improve the current situation. This presents an immediate opportunity to enhance tree establishment in our urban environment by simply integrating and applying existing knowledge more effectively.

Urban trees remain highly relevant to the built environment and society. However, their value can only be realised if trees are managed effectively from the inception of a planting scheme to full maturity in the landscape.

## References


ALLEN, R.G., PEREIRA, L.S., RAES, D. AND SMITH, M. (1999). *Crop Evapotranspiration (Guidelines for computing crop water requirements)*. FAO Irrigation and Drainage Paper No.56. Food and Agriculture Organisation, Rome.

APPLETON, B.L., CANNELLA, C.M., WISEMAN, P.E. AND ALVEY, A.A. (2008). Tree stabilization: current products and practices. *Arboriculture and Urban Forestry* **34**, 54–58.

ARNOLD, M.A. (1987). *Cupric carbonate modification of* Quercus rubra *and* Fraxinus pennsylvanica *root systems and implications for production and transplant*. MSc, The Ohio State University.

ARNOLD, M.A., MCDONALD, G.V., BRYAN, D.L., DENNY, G.C., WATSON, W.T. AND LOMBARDINI, L. (2007). Below-grade planting adversely affects survival and growth of tree species from five different families. *Arboriculture and Urban Forestry* **33**, 64–69.

BARNES, S. AND PERCIVAL, G.C. (2006). The influence of biostimulants and water-retaining polymer root dips on survival and growth of newly transplanted bare-rooted silver birch and rowan. *Journal of Environmental Horticulture* **24**, 173–179.

BRADY, N.C. AND WEIL, R.R. (2008). *The nature and properties of soils*. Prentice Hall, Harlow.

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II. A new survey of urban trees in England and their condition and management*. Department for Communities and Local Government.

BROWN, G.E. AND KIRKHAM, T. (2004). *The pruning of trees, shrubs and conifers*. Timber Press.

BUÉE, M., BOER, W.D. AND MARTIN, F. (2009). The rhizosphere zoo: An overview of plant-associated communities of microorganisms, including phages, bacteria, archaea, and fungi, and of some of their structuring factors. *Plant and Soil* **321**, 189–212.

CHALKER-SCOTT, L. (2007). Viewpoint impact of mulches on landscape plants and the environment – a review. *Journal of Environmental Horticulture* **25**, 239–249.

CLARK, R. (2003). *Specifying Trees: A guide to the assessment of tree quality*, NATSPEC, Sydney.

COSTELLO, L.R., MATHENY, N.P. AND CLARK, J.R. (2000). *A guide to estimating irrigation water needs of landscape plantings in California*. University of California Cooperative Extension.

COUENBERG, E. (1994). Amsterdam Tree Soil. *In:* Watson, G.W. and Neely, D., (eds.) *The Landscape Below Ground*. 1993 The Morton Arboretum. International Society of Arboriculture, pp. 24–33.

CRAUL, P.J. (1992). *Urban Soil in Landscape Design*. John Wiley & Sons, New York.

CRAUL, P.J. (1999). *Urban soils: applications and practices*, Wiley.

DAVIES, M.J., HIPPS, N.A. AND KINGSWELL, G. (2002). The effects of indole-3-butric acid root dips on the development and shoot growth of transplanted *Fagus sylvatica* L. and *Quercus robur* L. seedlings. *Journal of Horticultural Science and Biotechnology* **77**, 209–216.

DAY, S. D. AND HARRIS, J. R. (2007). Fertilization of red maple (Acer rubrum) and littleleaf linden (Tilia cordata) trees at recommended rates does not aid tree establishment. *Society* **33**, 113–121.

EISSENSTAT, D.M. AND YANAI, R.D. (2002). Root life span, efficiency, and turnover. *In:* Waisel, Y., Eshel, A. and Karkafi, U. (eds.) *Plant Roots: The Hidden Half.* Third edition. Revised and Expanded. CRC Press, pp. 221–238.

FELIX, P. (2004). Radical excavations and sheet excavations. September edition. *Tree care industry*, 8–12.

FINI, A., FERRINI, F., FRANGI, P., AMOROSO, G. AND PIATTI, R. (2009). Withholding irrigation during the establishment phase affected growth and physiology of Norway Maple (*Acer platanoides*) and Linden (*Tilia* spp.). *Arboriculture and Urban Forestry* **35**, 241–251.

FITE, K., WELLS, C.E. AND SMILEY, E.T. (2009). Impacts of Root Invigoration$^{TM}$ and its individual components on red maple (*Acer rubrum*) at four urban sites. *In:* Watson, G. W., Costello, L.R., Scharenbroch, B.C. and Gilman, E.F. (eds.) *The Landscape Below Ground III.* International Society of Arboriculture, Lisle, Illinois, pp. 55–61.

FOREST RESEARCH (2010). *Benefits of green infrastructure: Report to Defra and CLG*. Forest Research, Farnham.

GILBERTSON, P. AND BRADSHAW, A.D. (1985). Tree survival in cities: the extent and nature of the problem. *Arboricultural Journal* **9**, 131–142.

GILBERTSON, P. AND BRADSHAW, A.D. (1990). The survival of newly planted trees in inner cities. *Arboricultural Journal* **14**, 287–309.

GILBERTSON, P., KENDLE, A.D. AND BRADSHAW, A. (1985). Root growth and the problem of trees in urban and industrial areas. *In:* Patch, D., (ed.) *Advances in Practical Arboriculture*. Forestry Commision Bulletin (FCBU065). HMSO, London, pp. 59–66.

GILMAN, E.F. (2002). *An illustrated guide to pruning*. Delmar Thomson Learning.

GILMAN, E.F., BLACK, R.J. AND DEHGAN, B. (1998). Irrigation volume and frequency and tree size affect establishment rate. *Journal of Arboriculture* **24**, 1–9.

GILMAN, E.F., GRABOSKY, J., STODOLA, A. AND MARSHALL, M.D. (2003). Irrigation and container type impact red maple (*Acer rubrum* L.) 5 years after landscape planting. *Journal of Arboriculture*, **29** 231–236.

GILMAN, E.F., STODOLA, A. AND MARSHALL, M.D. (2002). Root pruning but not irrigation in the nursery affects live oak root balls and digging survival. *Journal of Environmental Horticulture* **28**, 122–126.

GRABOSKY, J. AND BASSUK, N.L. (1995). A new urban tree soil to safely increase rooting volumes under sidewalks. *Journal of Arboriculture* **21**, 187–201.

GRIMSHAW, J. AND BAYTON, R. (2010). *New Trees: Recent Introductions to Cultivation*. Royal Botanic Gardens, Kew.

HARRIS, J.R. AND FANELLI, J. (1998). Root pruning red maple and Washington hawthorn liners does not affect harvested root length aftern two years of field production. *Journal of Environmental Horticulture* **16**, 127–129.

HARRIS, R.W., CLARK, J.R. AND MATHENY, N.P. (2004). *Arboriculture: Integrated Management of Trees Shrubs and Vines*. Prentice Hall, Harlow.

HASCHER, W. AND WELLS, C.E. (2007). Effects of soil decompaction and amendment on root growth and architecture in Red Maple (*Acer rubrum*). *Arboriculture and Urban Forestry* **33**, 428–432.

HIEMSTRA, J.A., SCHOENMAKER, E. AND TONNEIJCK, A.E.G. (2008). *Trees: Relief for the City*. Plant Publicity, The Netherlands.

JOHNSTON, M. AND RUSHTON, B.S. (1999). *A survey of urban forestry in Britain*. University of Ulster, Ireland.

KOPINGA, J. (1991). The effects of restricted volumes of soil on the growth and development of street trees. *Journal of Arboriculture* **17**, 57–63.

KOSOLA, S., WORKMASTER, B.A.A., BUSSE, J.S. AND GILMAN, J.H. (2007). Sampling damage to tree fine roots: Comparing air excavation and hydropneumatic elutriation. *Hortscience* **42**, 728–731.

KOZLOWSKI, T.T., KRAMER, P.J. AND PALLARDY, S.G. (1991). *The Physiological Ecology of Woody Plants*. Academic Press.

KOZLOWSKI, T.T. (1999). Soil Compaction and Growth in Woody Plants. *Scandinavian Journal of Forest Research* **14**, 596-619.

KRAMER, P.J. AND BOYER, J.S. (1995). *Water Relations of Plants and Soils*. Academic Press.

KRISTOFFERSEN, P. (1998). Designing urban pavement sub-bases to support trees. *Journal of Arboriculture* **24**, 121–126.

LARCHER, W. (2003). *Physiological plant ecology: ecophysiology and stress physiology of functional groups*, Springer.

LINDQVIST, H. AND ASP, H. (2002). Effects of lifting date and storage time on changes in carbohdrate content and photosynthetic efficiency in three deciduous species. *Journal of Horticultural Science and Biotechnology,* **77**, 346–354.

LINDSEY, P. AND BASSUK, N.L. (1991). Specifying soil volumes to meet the water needs of mature urban street trees and trees in containers. *Journal of Arboriculture*, **17**, 141–149.

LINDSEY, P. AND BASSUK, N.L. (1992). Redesigning urban forests from the ground below: A new approach to specifying adequate soil volumes for street trees. *Arboricultural Journal* **16**, 25–39.

MARTINEZ-TRINIDAD, T., WATSON, T., ARNOLD, M.A. AND LOMBARDINI, L. (2009A). Carbohydrate injections as a potential option to improve growth and vitality of live oaks. *Arboriculture and Urban Forestry* **35**, 142–147.

MARTINEZ-TRINIDAD, T., WATSON, T., ARNOLD, M.A. AND LOMBARDINI, L. (2009B). Investigations of exogenous applications of carbohydrates on the growth and vitality of live oaks. *Urban Forestry & Urban Greening* **8**, 41–48.

MARTINEZ-TRINIDAD, T., WATSON, T., ARNOLD, M.A. AND LOMBARDINI, L. (2009C). Temporal and spacial glucose and starch partitioning in live oak. *Arboriculture and Urban Forestry* **35**, 63–67.

NIINEMETS, Ü. AND VALLADARES, F. (2006). Tolerance to shade, drought, and waterlogging of temperate northern hemisphere trees and shrubs. *Ecological Monographs* **76**, 521–547.

NUFU (2005). *Trees Matter! Bringing lasting benefits to people in towns.* National Urban Forestry Unit.

PALLARDY, S.G. (2008). *Physiology of Woody Plants*. Academic Press.

PERCIVAL, G.C. (2007). Pre-planting – getting to the root of the problem. June edition. *EssentialARB* **22**, 18–24.

PERCIVAL, G.C. AND BARNES, S. (2007). The influence of carbohydrates, nitrogen fertilisers and water-retaining polymer root dips on survival and growth of newly planted bare-rooted silver birch (*Betula pendula* Roth.) and European beech (*Fagus sylvatica* L.). *Arboricultural Journal* **30**, 1–22.

PERCIVAL, G.C. AND FRASER, G.A. (2005). Use of sugars to improve root growth and increase transplant success of Birch (*Betula pendula* Roth.). *Journal of Arboriculture* **31**, 66–78.

PERCIVAL, G.C., GKLAVAKIS, E. AND NOVISS, K. (2009). The influence of pure mulches on survival, growth and vitality of containerised and field planted trees. *Journal of Environmental Horticulture* **27**, 200–206.

PERCIVAL, G.C. AND HITCHMOUGH, J. (1995). Tree establishment and performance in a cool growing season arboretum. *Arboriculture Journal* **19**, 357–371.

POUYAT, R.V., SZLAVECZ, K., YESILONIS, I.D., GROFFMAN, P.M. AND SCHWARZ, K. (2010). Characteristics of urban soils. *In:* Aitkenhead-Peterson, J. and Volder, A. (eds.) *Urban Ecosystem Ecology.* American Society of Agronomy, pp. 119–152.

RICHARDSON-CALFEE, L.E., HARRIS, R.J. AND FANELLI, J.K. (2004). Seasonal effects of transplanting on Northern Red Oak and Willow Oak. *Journal of Environmental Horticulture* **22**, 75–79.

SCHARENBROCH, B.C. AND LLOYD, J.E. (2006). Particulate organic matter and soil nitrogen availability in urban landscapes. *Arboriculture & Urban Forestry* **32**, 180-191.

SELLMER, J. AND KUHNS, L. (2007). Guide to selecting and specifying nursery stock. *In:* Kuser, J. E. (ed.) *Urban and Community Forestry in the Northeast*. Second edition. Springer.

SINGLE, J. AND SINGLE, S. (2010). Good roots matter from day one. *Sibbaldia: The Journal of Botanic Garden Horticulture* **8**, 179–187.

SMILEY, E.T. (1994). The effects of soil aeration equipment on tree growth. *In:* Watson, G. W. and Neely, D. (eds.) *The Landscape Below Ground*. The Morton Arboretum. International Society of Arboriculture, pp. 207–210.

SMILEY, E.T. (1999). Air excavation: the next arboricultural frontier. December edition. *Arbor Age* **19**(12), 8–10.

SMILEY, E.T., CALFEE, L., FRAEDRICH, B.R. AND SMILEY, E.J. (2006). Comparison of structural and noncompacted soils for trees surrounded by pavement. *Arboriculture and Urban Forestry* **32**, 164–169.

SMILEY, E.T., MARX, D.H. AND FRAEDRICH, B.R. (1997). Ectomycorrhizal fungus innoculations of established residential trees. *Journal of Arboriculture* **23**, 113–115.

SMILEY, E.T., WATSON, G.W., FRAEDRICH, B.R. AND BOOTH, D.C. (1990). Evaluation of soil aeration equipment. *Journal of Arboriculture* **16**, 118–123.

SOLOTAROFF, W. (1911). *Shade Trees in Towns and Cities.* John Wiley & Sons, New York.

STRUVE, D.K. (1990). Root regeneration in transplanted deciduous nursery stock. *HortScience* **25**, 266–270.

TROWBRIDGE, P.J. AND BASSUK, N.L. (2004). *Trees in the Urban Landscape: Site assessment, design and installation*. John Wiley & Sons.

URBAN, J. (2008). *Up By Roots: Healthy soils and trees in the built environment*. International Society of Arboriculture.

WATSON, G.W. (1994). Root growth response to fertilizers. *Journal of Arboriculture* **20**, 4–8.

WATSON, G. W., CLARK, S. AND JOHNSON, K. (1990). Formation of girdling roots. *Journal of Arboriculture* **16**, 197–202.

WATSON, G.W. AND HIMELICK, E.B. (1982). Root distribution of nursery trees and its relationship to transplanting success. *Journal of Arboriculture* **8**, 225–229.

WATSON, G.W. AND HIMELICK, E.B. (1997). *Principles and Practices of Planting Trees and Shrubs.* International Society of Arboriculture, Champaign. IL.

WATSON, G.W. AND SYDNOR, T.D. (1987). The effect of root pruning on the root system of nursery trees. *Journal of Arboriculture* **13**, 126–130.

ZAINUDIN, S.R., AWANG, K. AND HANIF, A.H.B.M. (2003). Effects of combined nutrient and water stress on the growth of *Hopea odorata* Roxb. and *Mimusops elengi* Linn. seedlings. *Journal of Arboriculture* **29**, 79–84.

ZANDSTRA, J.W. AND LIPTAY, A. (1999). Nutritional effects on transplant root and shoot growth – A review. *Acta Horticulturae,* **504** 23–32.

# Fifteen years of urban tree planting and establishment research


## Abstract

Over 200 research papers related to urban tree planting and establishment have been published since 1997. Major topics include causes of deep root systems, load-bearing soils, estimation of root space requirements, installation of root paths, use of pervious pavements, prevention of root defects in containers, a new bare root transplanting method, use of soil applied growth stimulators at planting, effectiveness of support systems, effects of mulch on soil biology, and new perspectives on tree selection. Published research is summarized and an extensive list of citations is included.


## Introduction

The last thorough review of the scientific literature pertaining to planting urban trees was over a decade ago (Watson and Himelick, 1997). There have been over 200 research papers published since then. Research in some areas, such as structural soils, was just beginning and has expanded. On some subjects work has continued at a substantial pace with new questions emerging and many questions still unresolved. An example of this would be container designs to prevent root defects. Yet other areas are being revisited with a new perspective, such as mulching with a focus on soil biology. Can all of this research help us to do a better job planting trees and in turn enhance post-planting survival?


**Keywords:**

container, load-bearing soil, mulch, mycorrhizae, root depth, stake


## Areas of expanded research

### Causes of deep root systems

Deep root systems have been recognized as a problem of urban trees since at least the 1980s (Berrang *et al*., 1985), but the extent and causes of the problem were not understood. Studies show that up to two thirds of the uppermost structural roots of street and park trees were more than 7.5 cm below the soil surface (Watson and Hewitt, 2006). Nursery practices were first blamed for deep root systems without supporting data (Berrang *et al*., 1985). More recently, research has shown that the uppermost roots can average 7.5–10 cm below the soil surface in the nursery fields, and in harvested root balls (Watson and Hewitt, 2006; Rathjens *et al*., 2007). The average depth may not be alarming in itself, but a substantial number of individual trees may have roots that are much deeper to achieve this average.

Nursery production practices can contribute to deep root systems. Root pruning seedlings produces adventitious roots at the cut end of the primary root that grow rapidly. Many of the small natural lateral roots above the regenerated roots may be lost. Honeylocust (*Gleditzia triacanthos*), sugar maple (*Acer saccharum*) and callery pear (*Pyrus calleryana*) can lose up to 60% of these lateral roots when transplanted as one-year-old seedlings (Hewitt and Watson, 2009). The vigorously growing adventitious roots produced at the cut end, combined with the loss of natural laterals, has the potential to develop an 'adventitious root flare' deeper in the soil than the natural root flare. The depth of the adventitious root flare is determined by the length of the primary root after pruning (Figure 1). Even if the tree is planted at the original depth and the graft union is visible above ground, the adventitious root flare can be 30 cm or more below the soil surface.


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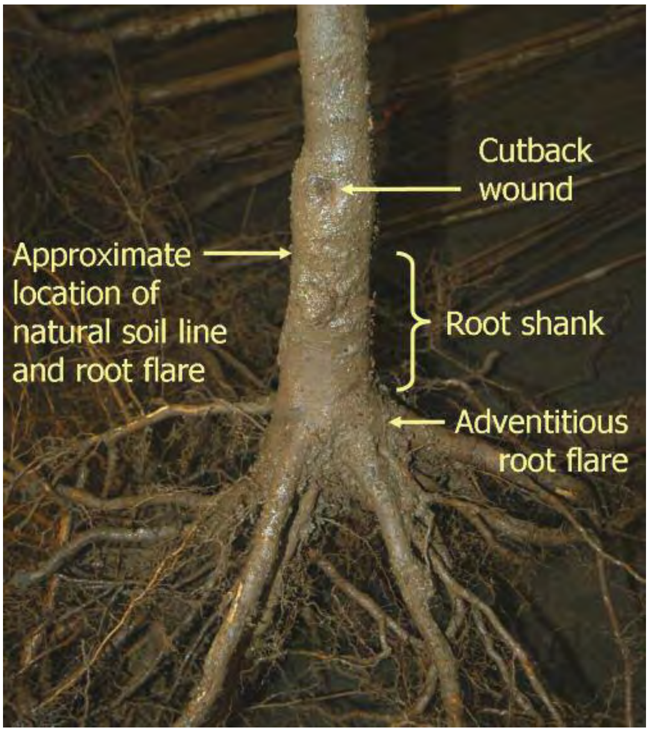
Figure 1 Vigorously growing adventitious roots regenerated after the primary root is pruned during production, combined with the loss of natural laterals, results in the formation of an 'adventitious root flare' deeper in the soil than the natural root flare. The depth of the adventitious root flare is determined by the length of the primary root after pruning (root shank).




Trees can be deliberately planted too deep in the field nursery in order to hide the graft union, reduce sprouting from the root stock, and protect the graft area from herbicides. When trees are planted with the graft below the soil, this increases root depth by an additional 5–10 cm. Soil accumulated around the base of the trunk accidentally from cultivation, or deliberately to deter weed seed germination, can increase root depth even more if not removed before harvesting. Though these trees with deep root systems can grow well in the high quality soil of the nursery, they may struggle to survive when harvested with the uppermost roots deep in the root ball and planted on difficult urban sites with heavy soils and poor drainage (Day and Harris, 2008).

Structural roots can be too deep in containers as well. Vigour can be reduced (Bryan *et al.*, 2010; Harris and Day, 2010). A dense mat of small roots can fill the soil above the woody roots that form the root flare and defects can be increased as roots are deflected up and back across the upper portion of the root ball (Fare, 2006; Gilman and Harchick, 2008). This can prevent planting the woody roots at the correct depth without removing a substantial portion of the roots in the root ball.

This concern over deep roots and root defects in the root ball has led to a practice of removing the soil or substrate from traditional root ball and container stock before planting bare root. The primary reason for it is to be able to see and correct root defects. This bare rooting process may limit the planting season compared to the original root ball stock, but both experience and research are limited at this point (Appleton and Flott, 2009).

## Load-bearing soils

Prior to the development of load-bearing (a.k.a. skeletal or structural) soils, the only option to provide root space under pavements was very expensive vaulted systems that suspend pavements above the soil in order to prevent compaction of the soil. Load-bearing soil must provide a favourable environment for root growth while also supporting the pavement. The first load-bearing soil was Amsterdam Tree Soil (Couenberg, 1993).

Amsterdam Tree Soil is a coarse sand mix carefully compacted to a specific density with aeration provided through spaces in the pavers placed over the soil. This system has been shown to be effective in providing vigorous trees and stable pavements for many years. More recently, other load-bearing soils types have been developed. Most load-bearing soils use stones to create a network of interconnected spaces that are filled with soil for root growth. Systems developed in Europe are often created on site by first putting down gap graded stone of preferred size, and then working the loam soil into the spaces between the stones with a mechanical vibrator. In the United States, pre-mixed soil is often transported to the installation site.

Early tests of load-bearing soil mixes in containers showed that stone-soil mixes could support better root and top growth than compacted soils or road base materials (Kristoffersen, 1999). The root-crown ratio was greater in stone mixes than topsoil alone (same soil volume), indicating a larger root system was needed for absorption of water and nutrients when the soil was diluted in the mix (Kristoffersen, 1999). Above-ground growth was limited by net soil volume rather than the total volume of the stone-soil mix (Loh *et al.*, 2003).

When mixed and installed properly, stone-soil mix compacted to 1.85g/cm$^3$, and greater, did not did not reduce macropores or restrict root penetration in the soil between the stones (Grabosky and Bassuk, 1996; Grabosky *et al.*, 2009). A stone-soil mix can hold 7–11% moisture by volume (similar to a loamy sand) with high infiltration, good drainage and aeration (Grabosky *et al.*, 2009).

In field studies at three and ten years after installation, growth (diameter breast height, height, canopy width) of trees growing in load-bearing soil and a nearby tree lawn was similar (Grabosky *et al.,* 2002; Grabosky and Bassuk, 2008). Contrary to this, other reports show that trees in non-compacted soils in open planters (Bühler *et al*., 2007) or covered by suspended pavement (Smiley *et al*., 2006), out-perform all structural soil mixes. Stone-soil mixes can be a useful compromise in situations where high quality non-compacted soils cannot be used, but will likely not support tree growth as well over time as the same volume of quality soil.

Trees were more stable in load-bearing soils than traditional tree pits due to greater root length in gravel-based skeletal soil (Bartens *et al*., 2010). This is supported by a computer model in which a 20% soil/80% granite chip mix was optimum for withstanding wind forces required to uproot trees (Rahardjo *et al*., 2009). Load-bearing soils can also provide stormwater storage (Day and Dickinson, 2008).

## Root paths

Root paths are narrow trenches installed in a compacted subgrade under pavement to provide a path for roots to grow from restricted planting pits to open spaces on the other side of the pavement. Commercially available strip drain material is usually installed in the trench and then backfilled with loam soil (Costello and Jones, 2003; Urban 2008). Paths can also connect individual planting pits to gain some of the benefits of a shared root space. This technique holds promise, but there is not yet any research available to support it.

## Pervious pavements

It has been suggested that pervious pavements would improve the soil environment beneath pavements for better tree growth, but research has not yet shown this to be consistently true. Soil oxygen was insufficient for root growth (<12%) for prolonged periods beneath two of five pervious paving products tested on park footpaths (Couenberg, 2009). There were no differences in soil oxygen and moisture between impervious and pervious pavements and no difference in tree growth rates, leaf water potential or gas exchange (Morgenroth and Buchan, 2009; Volder *et al*., 2009). The latter two studies were conducted on research plots with pavement less than 1.5 m wide and water and oxygen may have been able to diffuse under the pavement from the edges just as easily as through the pores. If soils are compacted under the non-porous pavements, the resulting poor soil aeration and penetration resistance itself are likely to be factors limiting root growth rather than the pavement type.

# Areas of continued research

## Container design

Many root problems in the landscape can be traced back to nursery containers. Because the natural spread of the root system is restricted by the container, lateral roots reaching the sides are redirected. There may be no difference in tree growth during nursery production or in the initial years after planting in the landscape (Gilman *et al*., 2003, 2010a), and so the problem can go undetected until it is too late to correct it.

Circling roots were first to be recognized as a problem. Circling roots can strangle the plant several years after planting as both the roots and the stem grow larger, especially if they are located on the top half of the root ball. Various pot designs with ridges and openings were developed to minimize circling roots as early as the 1980s (Appleton, 1993). Tests of numerous container designs have shown that they can reduce the number of circling roots, but ascending, descending or kinked roots can still develop (Marshall and Gilman, 1998; Gilman *et al*., 2009; Amoroso *et al*., 2010; Gilman *et al*., 2010a).

Root defects caused by container walls persist after repotting or transplanting unless pruned (Zahreddine *et al*., 2004), and therefore many defects are hidden from view because they are found below the substrate surface (Gilman *et al*., 2010b). Multiple layers of circling roots that develop within the root ball from successive stages of production can be difficult to detect and impossible to correct.

Vertically slicing the root ball edges reduces circling roots, but not descending roots or interior layers of circling roots (Gilman *et al*., 2009). Descending roots do not stabilize the tree as well as the normal horizontal radially-oriented roots. Trees from containers had one quarter the root cross sectional surface area into landscape soil compared to field-grown trees, further reducing stability (Gilman and Masters, 2010). Root ball shaving to remove all roots on the surface of the root ball can eliminate the descending roots and produce a more normal root system with many radially-oriented roots (Gilman *et al*., 2010).

## Growth stimulators

Many compounds have been marketed as biostimulants to be applied to the soil at planting. Contents of these may include growth hormones, nutrients, vitamins, sugars, amino acids, humic acids, extracts of plants, and beneficial rhizosphere fungi and bacteria.

Application of organic products, such as humates and plant extracts, at planting have shown only limited benefit to root or shoot growth of trees. Species vary widely in their response (Kelting *et al*., 1998a, 1998b; Ferrini and Nicese, 2002; Fraser and Percival 2003; Gilman, 2004; Sammons and Struve, 2004).

Sugars have been tested as a post-planting treatment to increase growth and establishment of trees. In most studies, the sugar was applied to the soil two or more times. Some sugars can increase root and shoot dry weight, and increase root-shoot ratio. Results are promising but inconsistent among species, sugars and application rates included in the limited trials (Percival, 2004, Percival and Fraser, 2005, Percival and Barnes, 2007, Martinez-Trinidad *et al*., 2009). It is not clear whether the soil-applied sugar increases beneficial rhizosphere organisms or is used directly by the tree.

Paclobutrazol, a growth regulator used primarily to reduce shoot growth on trees, can also increase root growth under certain circumstances. Paclobutrazol applied at planting doubled root growth on black maple (*Acer nigrum*) in the first season, but not the second. The lack of root response in the second season may be related to overall growth rate of the tree. The growth regulating effects of the spring-applied paclobutrazol were delayed until the second season, when shoot extension and leaf size were only 5 and 30% of control trees, respectively. This strong above-ground growth reduction likely caused the lack of root response in the second season. Growth of green ash (*Fraxinus pennsylvanica*) roots was unaffected by paclobutrazol treatment in either year (Watson, 2004). Gilman (2004) reported that paclobutrazol slowed top growth but did not affect root growth of transplanted live oaks (*Quercus virginiana*).

The benefits of mycorrhizal associations of tree roots are well known. Inoculations with mycorrhizal fungi have proven beneficial to trees when planted in soils lacking the appropriate fungi, such as strip mine reclamation sites. Urban planting sites can be of very poor quality, but they do not always lack appropriate mycorrhizal fungi for trees.

Mycorrhizal colonization of littleleaf linden (*Tilia cordata*) street trees and forest trees were similar (Timonen and Kauppinen, 2008). Mycorrhizal inoculum present in urban soils was greater than in forest soil (Wiseman and Wells, 2005). Growth rate has generally been unaffected when trees are treated with commercial inoculants at planting (Gilman, 2001; Ferrini and Nicese, 2002; Abbey and Rathier, 2005; Corkidi *et al*., 2005; Wiseman and Wells, 2009). Colonization can increase after planting without inoculation (Wiseman and Wells, 2009). The quality of the inoculum may be a factor. Mycorrhizal colonization of roots rarely exceeded 5% after treatment with commercial inoculants, but roots were up to 74% colonized when treated with lab-cultured inoculant (Wiseman *et al*., 2009).

## Support systems

The need to stake newly planted trees and methods of staking continue to be researched. Unstaked field-grown trees transplanted with soil balls remained upright in ambient wind conditions and were tolerant of moderate to heavy simulated wind loads in pulling tests seven months after planting (Alvey *et al*., 2009). Bare root and container-grown trees may require support until lateral or anchor roots develop, but seldom more than one year (Eckstein and Gilman, 2008).

Two stakes with separate flexible ties are commonly used but provided inadequate support when tested (Eckstein and Gilman, 2008). The depth to which the stakes are driven into the ground is a factor in the strength of the two-stake system. Three stakes may provide better support (Alvey *et al*., 2009). Three-point guying systems and root ball stabilization systems that have structure or straps over the root ball (Figure 2) and are anchored into the soil at the bottom of the planting hole provide the best support. (Eckstein and Gilman, 2008; Alvey *et al*., 2009).

Figure 2 Research shows that root ball stabilization systems that have structure or straps over the root ball provide the best support. Some systems have straps over the root ball that are anchored into the soil at the bottom of the planting hole instead of stakes (Eckstein and Gilman, 2008).

Soil balls need to be supported during handling and transport. Traditional burlap and twine are sometimes chemically treated to slow degradation. These treated materials can still be intact and very strong after two years, and starting to girdle roots (Kuhns, 1997). Wire baskets are often used in place of twine. Gauge of the metal used varies and little formal research has been done on the speed at which the wire rusts away. Thicker gauge wire baskets have been observed to still be minimally rusted after 25 years (Watson and Himelick, 1997)

# New perspectives on traditional topics

## Mulch

Research on the use of mulch has been reported for decades and the basic benefits are well established and still being reinforced. Mulch can increase growth and establishment of newly planted trees (Cogger *et al*., 2008; Ferrini *et al*., 2008; Arnold and McDonald, 2009; Percival *et al*., 2009). Mulch did not improve establishment of North American desert plants (Singer and Martin, 2009).

Growth increases are likely due to increased moisture availability due to reduced evaporation from the soil surface. However, when rainfall or irrigation is light, the mulch can reduce the amount of moisture reaching the root ball (Gilman and Grabosky, 2004; Arnold *et al*., 2005).

Most trees benefit from complex fungal dominated soil microflora, such as is developed under the litter layer in established woodlands over long periods of time. Disturbed urban soils, where trees are often planted, are often bacteria dominated and are more typical of grassland plant communities. Optimum tree health is dependent on re-establishment of fungal dominated soil biology. Application of mulch can enhance successional processes by which soil biology becomes progressively more complex, the ratio of fungi to bacteria increases, and tree growth increases (Soil and Water Conservation Society, 2000).

## Bare root transplanting

The traditional method of bare root transplanting has been mostly replaced over time by root ball stock because the planting season is more extended. The Missouri gravel bed system produces large fibrous root systems and allows bare root stock to be planted throughout the growing season. Bare root trees are heeled in a bed of 6.4 mm screened pea gravel mixed with 10% (by weight) masonry sand (Starbuck *et al*., 2005) or 40% calcined clay for greatly increased water holding capacity (Bohnert *et al*., 2008). Contractors are once again transplanting large trees bare root as they were before heavy equipment was available to move large, heavy root balls. Pneumatic excavation tools have made excavation of the root systems easier. Trees up to 66 cm dbh have been moved successfully according to anecdotal reports, but there is no published research on transplant survival and establishment rates.

## Tree selection

Diversity is often lacking in urban landscapes. It is not unusual to have large numbers of popular species planted in cities. In Hong Kong, the top ten dominant species are 55.7% of the population, and *Aleurites moluccana* constitutes 12.9% of the tree population (Jim, 1997). In Chicago, the ten most common species account for 45.7% of the urban trees (Nowak *et al*., 2010). In Nordic cities, 30–90% of all trees planted are a single species (Sæbø *et al*., 2003). In other European cities, only 3–5 genera usually accounted for 50–70% of all street trees planted (Pauleit *et al*., 2002).

Though a few popular species are often overplanted, many urban areas are actually repositories for a wide range of diverse plant materials. Many cities may have upwards of 100 or more tree species planted on the streets. In milder climates, some cities have a greater number of diverse species (Bassuk, 1990; Jim, 1997). Unfortunately, most of the species are planted in very small numbers. In California, most municipal arborists indicated that species diversity was an objective of managing tree selection, but less than half actually included this in their management plans. Approved species on planting lists were much narrower than the species variety in the current inventory (Muller and Bornstein, 2010).

Concern over invasive species is growing. Invasive plants are those introduced species that can thrive in areas beyond their natural range of dispersal, are adaptable, are aggressive, and have a high reproductive capacity. Their vigour, combined with few serious disease or insect pests, often lead to outbreak populations that can dominate natural plant communities. Many municipal planting lists include some moderately invasive species. Many invasive species have characteristics that would make them the kind of 'hardy or tough trees' needed on some urban sites. Protecting against invasive species was, however, not a concern of most arborists in California (Muller and Bornstein, 2010).

Climate change may affect urban trees through rising average temperatures and changes in the amount and seasonal distribution of precipitation. Though the effects will differ somewhat from region to region, lengthening of growing seasons and changes in the range and distribution of plants are expected. Trees will be affected not only by overall temperature increases, but also by extended periods of extreme heat and cold temperatures and by frequency and severity of storm events.

Changes in plant hardiness zones have already been documented in the United States (Arbor Day Foundation, 2006). Average minimum temperatures have increased by one zone (5°C) in many areas. To some extent, less hardy plants can be used further north than in the past. However, change is slow and a single extreme cold weather event can damage or kill trees after they have been growing successfully for many years. Incorporating climate change into planting programmes can be challenging. Trees in urban areas are not as long lived as their counterparts in the natural forest. The need to consider climate change in tree selection may vary by land use. Mortality rates of trees in developed areas vary by land use (Nowak *et al*., 2004). The average life expectancy of trees planted in commercial and industrial areas may be as little as ten years, while trees may live nearly 50 to 75 years in low density residential areas.

## Root space requirements

Tree root space requirements have been recommended at 0.03–0.06 $m^3$ of soil for each 1–2 $m^2$ of crown projection area of the expected mature size of the tree if above- and below-ground environmental extremes are not severe (Kopinga, 1985; Lindsey and Bassuk, 1991; Urban, 1992). More recently, a computer model has been developed that uses climatological data to estimate the soil volume necessary to provide moisture during the driest growing conditions likely to be encountered for an area. The example used is New York City where a 6 m crown diameter tree (28 $m^2$ crown projection area) with 17 $m^3$ of soil as recommended by Lindsey and Bassuk (1991), and without irrigation, would face a water deficit every other year (Figure 3). With 27.4 $m^3$ of soil, the tree would face a deficit only once in 10 years, but with only 4.3 $m^3$ of root space soil, the tree would need irrigation every fifth day to face a deficit only once in 10 years (DeGaetano, 2000). Using a different method, Blunt (2008) calculated that under British weather conditions a mature tree (size and species not specified) would require at least 50 $m^3$ of high quality soil with soil moisture recharged by rainfall or irrigation ten times during the growing season.

Figure 3 Each tree in a shared planting space of this size could have a crown diameter of no more than 4 m or be subject to annual drought stress without supplemental irrigation according to a computer model (DeGaetano, 2000).

## Incorporation of research into practice

The true test of the value of this research is whether it is used. Individual practitioners are often eager to adopt new practices. Sometimes the slowness at which information is incorporated into national standards and best management practices can be a limiting factor. Standard revisions do not occur frequently, and the most recent research may not be included for years until after it is accepted widely. The BS 4043 Recommendations for Transplanting Root-balled Trees was last revised in 1989. The American Standard for Nursery Stock was last updated in 2004. Revisions of both of these standards are underway. Florida Grades and Standards for Nursery Stock is one of the most comprehensive grading systems published. It was written in 1998 with a minor update released in 2005. The ANSI A300 (Part 6) American National Standard for Tree Care Operations – Transplanting was published in 2005. Most of these publications are years in preparation before the publication date.

Professional associations may be able to incorporate new research more quickly into best management practices, but even those are revised infrequently despite good intentions (Watson and Himelick, 2005). There is also danger that revising practices based on limited new research will not stand the test of time. Changes in practice should be based on sound peer-reviewed research confirmed by multiple studies.

## References


ABBEY, T. AND RATHIER, T. (2005). Effects of mycorrhizal fungi, biostimulants and water absorbing polymers on the growth and survival of four landscape plant species. *Journal of Environmental Horticulture* **23**, 108–111.

ALVEY, A.A., WISEMAN, P.E. AND KANE, B. (2009). Efficacy of conventional tree stabilization systems and their effect on short-term tree development. *Arboriculture and Urban Forestry* **35**, 157–164.

AMOROSO, G., FRANGI, P. AND PIATTI, R. (2010). Effect of container design on plant growth and root deformation of littleleaf linden and field elm. *HortScience* **45**, 1824–1829.

APPLETON, B.L. (1993). Nursery production alternatives for reduction or elimination of circling tree roots. *Journal of Arboriculture* **19**, 383–388.

APPLETON, B. AND FLOTT, J. (2009). Bare root to bare root – coming full circle. *In:* Watson, G. *et al*. (eds.) *The Landscape Below Ground III*. International Society of Arboriculture, Champaign, Illinois, pp. 178–181.

ARBOR DAY FOUNDATION (2006). *arborday.org Hardiness Zone Map*. Arbor Day Foundation, Nebraska City, Nebraska. [Online] Available at: http://www.arborday.org/media/zones.cfm [Accessed March 2011].

ARNOLD, M.A. AND MCDONALD, G.V. (2009). Groundcovers, organic and inorganic mulches, and masonry surfaces differentially affect establishment and root zone characteristics of urban trees. *Arboriculture and Urban Forestry* **35**, 232–240.

ARNOLD, M.A., MCDONALD, G.V. AND BRYAN, D.L. (2005). Planting depth and mulch thickness affect establishment of green ash (*Fraxinus pennsylvanica*) and bougainvillea goldenraintree (*Koelreuteria bipinnata*). *Journal of Arboriculture* **31**, 163–167.

BARTENS, J., WISEMAN, P.E. AND SMILEY, E.T. (2010). Stability of landscape trees in engineered and conventional urban soil mixes. *Urban Forestry and Urban Greening* **9**, 333–338.

BASSUK, N.L. (1990). Street tree diversity: Making better choices for the urban landscape. *In: Proceedings of the 7th METRIA Conference*. (Lisle, Illinois, USA., 1990). Metropolitan Tree Improvement Alliance, pp. 71–78.

BERRANG, P., KARNOSKY, D.F. AND STANTON, B.J. (1985). Environmental factors affecting tree health in New York City. *Journal of Arboriculture* **11**, 185–189.

BLUNT, S.M. (2008). Trees and pavements – are they compatible? *Arboricultural Journal* **31**, 73–80.

BOHNERT, C.A., STARBUCK, C. AND ANDERSON, S. (2008). Amending a gravel based growing medium with calcined clay improves physical properties and seedling growth. *Journal of Environmental Horticulture* **26**, 149–156.

BRYAN, D.L., ARNOLD, M.A., VOLDER, A., WATSON, W.T., LOMBARDINI, L., SLOAN, J.J., VALDEZ-AGUILAR, L.A. AND CARTMILL, A.D. (2010). Planting depth during container production and landscape establishment affects growth of *Ulmus parvifolia*. *HortScience* **45**, 54–60.

BÜHLER, O., KRISTOFFERSEN, P. AND LARSEN, S.U. (2007). Growth of street trees in Copenhagen with emphasis on the effect of different establishment concepts. *Arboriculture and Urban Forestry* **33**, 30–337.

COGGER, C., HUMMEL, R., HART, J. AND BARY, A. (2008). Soil and redosier dogwood response to incorporated and surface-applied compost. *HortScience* **43**, 2143–2150.

CORKIDI, L., ALLEN, E.B., MERHAUT, D., ALLEN, M.R., DOWNER, J., BOHN, J. AND EVANS, M. (2005). Effectiveness of commercial mycorrhizal inoculants on the growth of *Liquidambar styraciflua* in plant nursery conditions. *Journal of Environmental Horticulture* **23**, 72–76.

COSTELLO, L.R. AND JONES, K.S. (2003). *Reducing infrastructure damage by tree roots: a compendium of strategies*. Western Chapter of the International Society of Arboriculture (WCISA), Cohasset, California.

COUENBERG, E.A.M., (1993). Amsterdam Tree Soil. *In:* Watson, G. and Neely, D. (eds.) *The Landscape Below*

*Ground.* International Society of Arboriculture, Savoy, Illinois, USA. pp 24–33.

COUENBERG, E.A.M. (2009). A preliminary study evaluating oxygen status beneath different surface-hardening materials for park use. *In:* Watson, G. *et al*. (eds.) *The Landscape Below Ground III*. International Society of Arboriculture, Champaign, Illinois, USA. pp 95–100.

DAY, S.D. AND DICKINSON, S.B. (EDS.) (2008). *Managing Stormwater for Urban Sustainability Using Trees and Structural Soils*. Virginia Polytechnic Institute and State University, Blacksburg, VA.

DAY, S.D. AND HARRIS, J.R. (2008). Growth, survival, and root system morphology of deeply planted *Corylus colurna* 7 years after transplanting and the effects of root collar excavation. *Urban Forestry and Urban Greening* **7**, 119–128.

DEGAETANO, A.T. (2000). Specification of soil volume and irrigation frequency for urban tree containers using climate data. *Journal of Arboriculture* **26**, 142–150.

ECKSTEIN, R. AND GILMAN, E.F. (2008). Evaluation of landscape tree stablilization system. *Arboriculture and Urban Forestry* **34**, 216–211.

FARE, D.C. (2006). *Should potting depth be a concern with container-grown trees?* The Morton Arboretum, Lisle, Illinois. [Online] Available at: http://www.mortonarb.org/deeptreeroots/pdf/GRR_Proceedings.pdf#page=26 [Accessed March 2011].

FERRINI, F., FINI, A., FRANGI, P. AND AMOROSO, G. (2008). Mulching of ornammetnal trees: effects on growth and physiology. *Arboriculture and Urban Forestry* **34**, 17–162.

FERRINI, F. AND NICESE, F.P. (2002). Response of English oak (*Quercus robur*) trees to biostimulants application in the urban environment. *Journal of Arboriculture* **28**, 70–75.

FRASER, G.A. AND PERCIVAL, G.C. (2003). The influence of biostimulants on growth and vitality of three urban tree species following transplanting. *Arboricultural Journal* **27**, 43–57.

GILMAN, E.F. (2001). Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of *Quercus virginiana*. *Journal of Arboriculture* **27**, 30–38.

GILMAN, E.F. (2004). Effects of amendments, soil additives, and irrigation on tree survival and growth. *Journal of Arboriculture* **30**, 301–310.

GILMAN, E.F. AND GRABOSKY, J. (2004). Mulch and planting depth affect live oak (*Quercus virginiana* Mill.) establishment. *Journal of Arboriculture* **30**, 311–316.

GILMAN, E.F., GRABOSKY, J., STODOLA, A. AND MARSHALL, M.D. (2003). Irrigation and container type impact red maple (*Acer rubrum* L.) 5 years after landscape planting *Journal of Arboriculture* **29**, 231–235.

GILMAN, E.F. AND HARCHICK, C. (2008). Planting depth in containers affects root form and tree quality. *Journal of Environmental Horticulture* **26**, 129–134.

GILMAN, E.F., HARCHICK, C. AND WIESE, C. (2009). Pruning roots affects tree quality in container-grown oaks. *Journal of Environmental Horticulture* **27**, 7–11.

GILMAN, E.F., HARCHICK, C. AND PAZ, M. (2010A). Effect of container type on root form and growth of red maple. *Journal of Environmental Horticulture* **28**, 1–7.

GILMAN, E.F., HARCHICK, C. AND PAZ, M. (2010B). Planting depth affects root form of three shade tree cultivars in containers. *Arboriculture and Urban Forestry* **36**, 132–139.

GILMAN, E.F. AND MASTERS, F.J. (2010). Effect of tree size, root pruning, and production method on root growth and lateral stability of *Quercus virginiana*. *Arboriculture and Urban Forestry* **36**, 281–291.

GILMAN, E.F., PAZ, M. AND HARCHICK, C. (2010). Root ball shaving improves root systems on seven species in containers. *Journal of Environmental Horticulture* **28**, 13–18.

GRABOSKY, J. AND BASSUK, N. (1996). Testing of structural urban tree soil materials for use under pavement to increase street tree rooting volumes. *Journal of Arboriculture* **22**, 255–263.

GRABOSKY, J. AND BASSUK, N. (2008). Sixth- and tenth-year growth measurements for three tree species in a load-bearing stone–soil blend under pavement and a tree lawn in Brooklyn, New York, US. *Arboriculture and Urban Forestry* **34**, 265–266.

GRABOSKY, J., BASSUK, N. AND MARRANCA, B.A. (2002). Preliminary findings from measuring street tree shoot growth in two skeletal soil installations compared to tree lawn plantings. *Journal of Arboriculture* **28**, 106–108.

GRABOSKY, J., HAFFNER, E. AND BASSUK, N. (2009). Plant available moisture in stone–soil media for use under pavement while allowing urban tree root growth. *Arboriculture and Urban Forestry* **35**, 271–278.

HARRIS, J.R. AND DAY, S.D. (2010). Planting depth at onset of container production and subsequent rootball remediation at transplanting of pin oak and littleleaf linden. *HortScience* **45**, 1793–1797.

HEWITT, A. AND WATSON, G. (2009). Bare root liner production can alter tree root architecture. *Journal of Environmental Horticulture* **27**, 99–104.

JIM, C.J. (1997). Roadside trees in urban Hong Kong: part II species composition. *Arboricultural Journal* **20**, 279–298.

KELTING, M., HARRIS, J.R. AND FANELLI, J. (1998A). Humate-based biostimulants affect early post-transplant root growth and sapflow of balled and burlapped red maple. *HortScience* **33**, 342–344.

KELTING, M., HARRIS, J.R. AND FANELLI, J. (1998B). Biostimulant soil amendments affect two-year posttransplant growth of red maple and Washington hawthorn. *HortScience* **33**, 819–822.

KOPINGA, J. (1985). Research on street tree planting practices in the Netherlands. *In: Proceedings of the 5th METRIA Conference.* (University Park, Pennsylvania, 1985). Metropolitan Tree Improvement Alliance, pp. 72–84.

KRISTOFFERSEN, P. (1999). Growing trees in road foundation materials. *Arboricultural Journal* **23**, 57–76.

KUHNS, J.R. (1997). Penetration of treated and untreated burlap by roots of balled-and-burlapped Norway maples. *Journal of Arboriculture* **23**, 1–6.

LINDSEY, P. AND BASSUK, N. (1991). Specifying soil volumes to meet the water needs of mature urban street trees and trees in containers. *Journal of Arboriculture* **17**, 141–148.

LOH, F.C.W., GRABOSKY, J.C. AND BASSUK, N.L. (2003). Growth response of *Ficus benjamina* to limited soil volume and soil dilution in a skeletal soils container study. *Urban Forestry and Urban Greening* **2**, 53–62.

MARSHALL, M.D. AND GILMAN, E.F. (1998). Effects of nursery container type on root growth and landscape establishment of *Acer rubrum* L. *Journal of Environmental Horticulture* **16**, 55–59.

MARTINEZ-TRINIDAD, T., WATSON, W.T., ARNOLD, M.A. AND LOMBARDINI, L. (2009). Investigations of exogenous applications of carbohydrates on the growth and vitality of live oaks. *Urban Forestry and Urban Greening* **8**, 41–48.

MORGENROTH, J. AND BUCHAN, G.D. (2009). Soil moisture and aeration beneath pervious and impervious pavements. *Arboriculture and Urban Forestry* **35**, 135–140.

MULLER, R.N. AND BORNSTEIN, C. (2010). Maintaining the diversity of California's municipal forests. *Arboriculture and Urban Forestry* **36**, 18–27.

NOWAK, D.J., HOEHN, R.E., CRANE, D.E., STEVENS, J.C. AND LEBLANC FISHER, C. (2010). *Assessing urban forest effects and values. Chicago's urban forest.* Resource Bulletin NRS-37. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, Pennsylvania.

NOWAK, D.J., KURODA, M. AND CRANE, D.E. (2004). Tree mortality rates and tree population projections in Baltimore, Maryland, USA. *Urban Forestry and Urban Greening* **2**, 139–148.

PAULEIT, S., JONES N., GARCIA-MARTIN, G., GARCIA-VALDECANTOS, J.L., RIVIÈRE, L.M., VIDAL-BEAUDET, L., BODSON, M. AND RANDRUP, T.B. (2002). Tree establishment practice in towns and cities – results from a European survey. *Urban Forestry and Urban Greening* **1**, 83–86.

PERCIVAL, G.C. (2004). Sugar feeding enhances root vigor of young trees following containerization. *Journal of Arboriculture* **30**, 357–364.

PERCIVAL, G.C. AND BARNES, S. (2007). The influence of carbohydrates, nitrogen fertilisers and water-retaining polymer root dips on survival and growth of newly transplanted bare-rooted silver birch (*Betula pendula* Roth.) and European beech (*Fagus sylvatica* L.). *Arboricultural Journal* **30**, 223–244.

PERCIVAL, G.C. AND FRASER, G.A. (2005). Use of sugars to improve root growth and increase transplant success of birch *(Betula pendula* Roth.). *Journal of Arboriculture* **31**, 66–77.

PERCIVAL, G.C., GKLAVAKIS, E. AND NOVISS, K. (2009). Influence of pure mulches on survival, growth and vitality of containerized and field planted trees. *Journal of Environmental Horticulture* **27**, 200–206.

RAHARDJO, H., HARNAS, F.R., LEONG, E.C., TAN, P.Y., FONG, Y.K. AND SIM, E.K. (2009). Tree stability in an improved soil to withstand wind loading. *Urban Forestry and Urban Greening* **8**, 237–247.

RATHJENS, R.G., SYDNOR, T.D. AND GARDNER, D.S. (2007). A survey of the depth of the main lateral roots of nursery trees in Ohio before and after harvest. *Journal of Environmental Horticulture* **25**, 187–190.

SÆBØ, A., BENEDIDZ, T. AND RANDRUP, T.B. (2003). Selection of trees for urban forestry in the Nordic countries. *Urban Forestry and Urban Greening* **2,** 101–114.

SAMMONS, J.D. AND STRUVE, D.K. (2004). Effect of Bioplex™ on transplant success of non-dormant red oak (*Quercus rubra* L.). *Journal of Environmental Horticulture* **22**, 197–201.

SINGER, C.K. AND MARTIN, C.A. (2009). Effect of landscape mulches and drip irrigation on transplant establishment and growth of three North American desert native plants. *Journal of Environmental Horticulture* **27**, 166–170.

SMILEY, E.T., CALFEE, L., FRAEDRICH, B.R. AND SMILEY, E.J. (2006). Comparison of structural and noncompacted soils for trees surrounded by pavement. *Arboriculture and Urban Forestry* **34**, 164–169.

SOIL AND WATER CONSERVATION SOCIETY (SWCS). (2000). *Soil Biology Primer*. Revised edition. Soil and Water Conservation Society, Ankeny, Iowa.

STARBUCK, C., STRUVE, D.K. AND MATHERS, H. (2005). Bare root and ball-and-burlapped red oak and green ash can be summer transplanted using the Missouri gravel bed system. *HortTechnology* **15**, 122–127.

TIMONEN, S. AND KAUPPINEN, P. (2008). Mycorrhizal colonization patterns of *Tilia* trees in street, nursery and forest habitats in southern Finland. *Urban Forestry and Urban Greening* **7**, 265–276.

URBAN, J. (1992). Bringing order to the technical dysfunction within the urban forest. *Journal of Arboriculture* **18**, 85–90.

URBAN, J. (2008). *Up by Roots: Healthy Soils and Trees in the Built Environment.* International Society of Arboriculture, Champaign, Illinois.

VOLDER, A., WATSON, T. AND VISWANATHAN, B. (2009). Potential use of pervious concrete for maintaining existing mature trees during and after urban development. *Urban Forestry and Urban Greening* **8**, 249–256.
WATSON, G. (2004). Effect of transplanting and paclobutrazol on root growth of 'Green Column' black maple and 'Summit' green ash. *Journal of Environmental Horticulture* **22**(4), 209–212.
WATSON, G.W. AND HEWITT, A.M. (2006). *Deep roots of landscape trees*. The Morton Arboretum, Lisle, Illinois. [Online] Available at: http://www.mortonarb.org/deeptreeroots [Accessed March 2011].
WATSON, G.W. AND HIMELICK, E.B. (1997). *Principles and practice of planting trees and shrubs*. International Society of Arboriculture, Champaign, Illinois.
WATSON, G. AND HIMELICK, E.B. (2005). *Best management practices – Tree planting*. International Society of Arboriculture, Champaign, Illinois.
WISEMAN, P.E., COLVIN, K.H. AND WELLS, C.E. (2009). Performance of mycorrhizal products marketed for woody landscape plants. *Journal of Environmental Horticulture* **27**, 41–50.
WISEMAN, P.E. AND WELLS, C.E. (2005). Soil inoculum potential and arbuscular mycorrhizal colonization of *Acer rubrum* in forested and developed landscapes. *Journal of Arboriculture* **31**, 296–302.
WISEMAN, P.E. AND WELLS, C.E. (2009). Arbuscular mycorrhizal inoculation affects root development of *Acer* and *Magnolia* species. *Journal of Environmental Horticulture* **27**, 70–79.
ZAHREDDINE, H.G., STRUVE, D.K. AND QUIGLEY, M. (2004). Growing *Pinus nigra* seedlings in Spinout™-treated containers reduces root malformation and increases growth after transplanting. *Journal of Environmental Horticulture* **44**, 176–182.

# Exploring the role of street trees in the improvement and expansion of green networks


## Abstract

One of the most important social benefits associated with green spaces and street trees, the building blocks of green networks, is their capacity to generate social action among local community members. Evidence also shows that formal community and stakeholder engagement is required for the effective and sustainable implementation of urban greening initiatives, such as the development of green networks. This paper examines the potential relationships between these two forms of social action. We consider the definition and composition of green networks, and their place in planning frameworks. We then describe the evidence relating to the social and cultural values of green spaces and street trees, focusing particularly on social action. In our discussion we think through how street trees might be used to 'pull people in' to participate in the expansion and improvement of green networks.


## Introduction

Evidence suggests that one of the key benefits associated with green spaces and street trees, the building blocks of 'green networks', is their capacity to generate social interaction (Dandy, 2010; Stewart *et al*., 2010). This is argued to derive primarily from the greater use of public areas by community members when trees are present and/or otherwise 'green': meaning that individuals are more likely to meet one another and utilise the space for outdoor activities and events. While this type of social action might be considered largely *ad hoc* and informal, research has linked it to the development of stronger, more stable, communities. Research and practice also shows that more formal or focused community and stakeholder engagement is vital for the successful implementation of urban greening initiatives in general. This paper explores the potential relationships between these two forms of social action, by thinking through how the social action generated by street trees might transform, or be transformed, into social action focused on the improvement and expansion of the green networks of which they are a part.

Green networks have emerged as an important element of planning policies across the UK and Europe, presenting a number of new challenges to land managers, planners and researchers, particularly those working in urban contexts. Perhaps one of the most important challenges is maximising community and stakeholder engagement with, and use of, green networks. While considerable knowledge and advice is available relating to engagement around individual green spaces and greening initiatives, there is far less evidence regarding how people and communities engage with more holistic entities such as green networks. Given the likely (default) focus on engagement through individual components of networks, such as street trees, it is of particular importance to understand if, how, when and where social action around these individual components might transform, or be transformed, into social action relating to the wider network.

We begin this paper by considering the definition and composition of green networks, their relationship with current planning policies, and the limited evidence on their capacity to 'pull people in' to participate and use them. We then describe the evidence relating to the social and cultural values of the components of green networks (i.e. green spaces and street trees) and provide practical examples of street tree projects. This section has a particular focus on the generation of social action. In our discussion we use street trees to think through how


**Keywords:**

green infrastructure, social action, social values, urban forests



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individual components of green networks might be used to 'pull people in' to participate in their expansion and development, and whether this approach maximises engagement with them.

# Green networks

## What is a 'green network'?

There are a number of definitions of the term 'green network' and this is further complicated by those definitions of 'green infrastructure' which incorporate concepts such as inter-relationships and landscape connectivity. These terms are often used interchangeably (Moseley and Marzano, in review). Tzoulas *et al*. (2007: 169) define green *infrastructure* as 'all natural, semi-natural and artificial networks of multifunctional ecological systems with, around and between urban areas, at all spatial scales', although this emphasises ecological, not social, networks. Forest Research (2010: 9) defines green infrastructure as 'the combined structure, position, connectivity and types of green spaces which together enable delivery of multiple benefits as goods and services'. This is being clearly echoed in green infrastructure strategies, for example Leeds City Region (LCR) defines green infrastructure as 'a combination of environmental assets and man-made features that have a semi-natural component' (LCR, 2010: 7), and these definitions have clear connotations of a *network*. In this paper we prefer the term *green network*, and wish to emphasise the idea that components encourage movement of, and provide environmental benefits for, both people and wildlife. Considering both ecological and social dimensions of green networks is crucial for effective planning and management. While ecological connectivity depends primarily on the juxtaposition of physical green spaces, obtaining the social benefits of green networks is also contingent upon the connectivity not only between physical features but also between these and the users of networks and their social institutions and practices (see Forest Research, 2010).

What makes up a green network? Green networks encompass multifunctional green spaces, but often also consider other (non-green) civic spaces. For many local authorities green network planning is still in its early stages and the precise composition of green networks may differ between individual local authorities reflecting the types of green space present. Within Scotland, the PAN 65 typologies relating to open space (Scottish Government, 2008) are used, ranging from formal areas such as public and private parks and gardens, amenity green spaces, playspaces and sport areas, to more natural areas such as woodlands, riparian routes and green access routes. Natural England (2009) defines five broad categories within a green infrastructure typology: parks and gardens; amenity greenspace; natural and semi-natural urban green spaces; green corridors; and an 'other' category covering allotments, community gardens, city farms, cemeteries and churchyards.

Green spaces can vary in size from large woodlands to small areas of amenity green space; all play a part in the connectivity of the green network. When examining the extent of a green network, it is easy to perceive that some areas appear to lack green spaces. However, closer examination may reveal that there are fingers of green reaching into the community; tree-lined avenues linking bigger green spaces to residential areas. Iconic large or old individual trees can provide focal points in addition to the more formal green space areas. Although street trees are often mentioned as contributing towards tree cover or the amount of green space, they are often not mapped as a component of the green network.

All these components contribute to the green network, although some may provide a greater range of benefits to a larger number of people. In order to maximise their individual contribution to the network, large (core) areas of green space providing a wide range of benefits should be protected and expanded; linkages to these core areas such as green corridors alongside rivers and disused railways, paths and cycleways should be maintained and improved; smaller areas of green space, such as street trees, which may not be currently linked to a network can provide stepping stones for species and people to access other parts of the green network and provide a focus for further improvement for its extent and connectivity. This may be undertaken through the planting of street trees and management of brownfield sites. Indeed, brownfield sites are increasingly being recognised explicitly as important parts of green networks; for example, 'areas of waste ground on former industrial sites can often be seen to perform a great many green infrastructure functions and are highly valued by the people that live in close proximity to them...' (LCR, 2010: 7).

Each of the green space types provides different functionalities and there will be variation in quality between sites (e.g. structural diversity of habitats, provision of play equipment, etc.) which can be captured through surveys and audits and used to plan and improve green networks. It is important that the quality as well as the quantity of the green spaces are improved. This may take the form of additional facilities or simply the greening of an area and its access routes by tree planting projects. The development of a green network might also involve increasing public accessibility and engagement through the provision of paths or the creation of areas of open space to promote health and wellbeing. These open spaces can also provide habitat for a range of wildlife species, help reduce flood risk and improve the economic status of an area, by making it a more attractive place to live and work. By spatially targeting where these activities are undertaken, linkages will be created, reducing habitat fragmentation and isolation, and extending the green network into local communities.

### Green networks and planning

Reference to green networks appears throughout planning documents, from National Planning Guidance to local plans, covering all types of green space and its functions for people, biodiversity and the environment. Within Scotland, *Scottish Planning Policy* (Scottish Government, 2010) supports green network development. Within England, guidance on undertaking green space audits, often a precursor for a green infrastructure strategy, is provided by Planning Policy Guidance 17 (PPG 17) *Planning for Open Space, Sport and Recreation* (CLG, 2002). In Scotland, the development of green networks has been championed by the Scottish Government and Regional Planning Authorities. For example, *National Planning Framework 2* has a vision 'to create a Central Scotland Green Network (CSGN) capable of delivering a step change in the quality of the environment for the benefit of people, landscape and nature' (Scottish Government, 2009: 33, paragraph 95). Launching the Edinburgh and Lothians Forest Habitat Network Partnership, the then Environment Minister, Michael Russell, stressed the importance of street trees in green networks. Having said this, the generally low profile of street trees within urban planning policies and definitions of green networks points to the fact that their current and future contribution, both ecologically and socially, to green networks appears to be vastly underestimated.

### 'Pulling people in' to urban green networks

Published evidence identifying which components of green networks act to 'pull people in' (i.e. generate use and participation), and how, is very limited. However, some evidence relating to expressed reasons for using green spaces holds some suggestions, although longitudinal studies are needed to monitor and evaluate these aspects of green networks. Over half the UK population (approximately 33 million people) make a total of 2.5 billion visits to urban green spaces annually (Wooley *et al*., 2004). How green spaces are used depends on individual preferences, needs and personal experience as well as age, ethnicity and gender (Cohen *et al*., 2007; Tyrväinen *et al*., 2007). Greenspace Scotland (2008) record use for a range of different activities including walking (49%), taking children out to play (26%), dog-walking (16%), relaxing (11%), exercise (9%), spending time with the family (8%), to pass through (5%), socialising with friends (3%) and having contact with other people (1%). The repeat survey in 2009 found that the primary uses of green space remain to go for a walk (49%) and a place for the children to play (27%). Pikora *et al*. (2003) note the key determinants influencing walking outdoors include aesthetics, safety and presence of destination.

Borst *et al*. (2008) reveal a positive relationship between the presence of street trees and preferred walking routes for elderly people, although a later study (Borst *et al*., 2009) did not show a significant relationship. Giles-Corti *et al.* (2005: 170) suggest that the attributes of 'public open spaces' influence how it is used and by whom. These include perceived proximity, accessibility, aesthetic features (presence of trees, water and wildlife), maintenance, and availability of amenities such as paths for walking. However, more work has been done on why people might *not* visit urban green spaces. Reasons include the presence of other users, including undesirable characters, and environmental quality issues (Dunnett *et al*., 2002: 11).

Aspects of this evidence seem to militate against the notion that green spaces can increase social action and interaction – especially expressed concern about encountering 'others'. However, it is likely that the problem here is with the research method and approach. 'Generating social action' is unlikely to appear on a survey of activities in, or reasons for using, green space, and is unlikely to be among explicit direct motivations for users. Building local capacity and a sense of ownership is, however, essential for ensuring the sustainability of any green network initiatives (Weldon and Bailey, 2007).

## The social values of urban green spaces and street trees

### Green spaces

There is now a substantial literature exploring the social benefits and values of urban green spaces. Overall, evidence suggests that they can provide numerous environmental, economic and social benefits to urban societies: and are thus very valuable. Much of this evidence has been generated by survey methods; however, evidence from wider sociological and anthropological qualitative studies is also valuable. For example, Venkatesh's (2006: 63–87) description and analysis of the importance of an urban park to a poor community in Chicago, and the substantial efforts community members will make to ensure the safety of its users despite its extremely poor quality 'facilities', is instructive. This section reviews the social benefits of urban green spaces in general then moves on to explore street trees in more depth. We focus particularly on the capacity of green spaces and street trees to generate social action.

Social benefits that can be derived from urban green spaces are varied. They include providing valuable assets for education and learning activities which can help people to connect with nature and enhance their appreciation and value for natural spaces (Konijnendijk, 2008; Lovell *et al*., 2010). Green spaces offer numerous opportunities for recreational activities and some studies have found associations between access to green space and greater levels of physical activity, which ultimately leads to improved health (Giles-Corti *et al.*, 2005; de Vries *et al*., 2011). It would appear that there is stronger evidence to support an association between green spaces and improved mental wellbeing through psychologically and physiologically restorative experiences which help enhance mood, and reduce stress and mental fatigue (Croucher *et al*., 2007; O'Brien *et al*., 2010; Stewart and O'Brien, 2010). These effects may be achievable not only through use of green spaces but also simply through access to views of green areas. The existence of green spaces and networks in urban areas also provides benefits in terms of improvements in the aesthetics of the urban landscape, with vegetation making areas more pleasant to live and work in as well as visit (Ellis *et al*., 2006; Chen and Jim, 2008). This can help people feel pride for their local area.

There is now a growing body of evidence that green spaces can help to facilitate social interaction and address issues of social inclusion, cohesion and community empowerment (Bell *et al*., 2008; Stewart *et al*., 2010; Stewart and O'Brien, 2010). They can act as platforms to help bring communities together and encourage people from different backgrounds and cultures to interact (Ravenscroft and Markwell, 2000; Bell *et al*., 2008; Seeland *et al*., 2009: 10). Green spaces, and in particular those with trees, have been shown to promote higher levels of use, social activity and interaction than non-green spaces (Coley *et al*., 1997; Sullivan *et al*., 2004). Moreover, evidence implies that individuals using green spaces often enjoy a stronger sense of community and perceive that they have greater social ties than those individuals who do not use the same green spaces (Kweon *et al*., 1998). Place attachment of this kind and strong community cohesion and interaction can encourage not only social but also political engagement and may lead to local residents becoming involved in the preservation, improvement and expansion of such spaces.

Taking this a step further, Elmendorf (2008: 154) supports the notion that if people and communities are engaged in the decision-making, implementation and monitoring processes involved in the planning, development and delivery of green space initiatives then significant social impacts may be felt. Communities may develop improved social structures and organisation through enhanced interaction and the building of capacity. 'Engagement' in this sense could include involvement in, for example, volunteer programmes, tree-planting events or 'citizen science' activities such as biodiversity surveys. Ultimately, also, enhanced engagement and participation can improve the likelihood that the landscape meets local needs, reflects local values and is 'owned' by the local community, which should in turn improve the chances that the potential benefits of green spaces and networks can be realised, particularly in terms of social benefits.

## Street trees

We have illustrated above the considerable literature on the benefits of green spaces, which has a substantial sub-focus upon urban forestry. Only a relatively small number of papers, however, address the social and cultural values of *street trees* specifically. Put simply, a 'street tree' is a tree located next to or within a public road. More precisely, a street tree is a tree located on land forming or adjacent to a 'highway' which affects, in some way, those using that highway. Street trees in the urban environment can have particular values which are being increasingly widely recognised (Read *et al*., 2009). A study by Welch (1994) indicated the structural distinctiveness of street trees from other elements of the 'urban forest', but further to this people interact with street trees in ways that can be different from how people interact with trees located elsewhere. Street trees also constitute a much larger proportion of total canopy cover in urban areas relative to rural areas. In urban areas they are, by and large, proximal to far greater numbers of people and buildings than their rural counterparts. This brings with it increased opportunities for interaction, both positive and negative. Of the published materials the vast majority of street tree-specific research has been conducted in North America, and nearly all of the studies are quantitative. A review of this limited literature identifies a number of benefits which urban communities can obtain from street trees. Attempts have been made to place economic valuations on the benefits of street trees; for example, estimates have been made that one scheme to plant a million trees in Los

Angeles will provide, over the next 35 years, between $1.33 billion and $1.95 billion of environmental and social benefits, with an average annual benefit of between $38 and $56 per tree (McPherson *et al*., 2010).

The aesthetic value of street trees has received considerable attention with research illustrating that people value street trees simply for their aesthetic attractiveness (Sommer and Sommer, 1989; Flannigan, 2005). Tree size is an important variable within this with the general preference for large, spreading, globular or round trees. Height has also been found to be an important variable (Kalmbach and Kielbaso, 1979; Williams, 2002).

It is likely that street trees have substantial restorative value. Considerable research (e.g. Kaplan and Kaplan, 1989; Kaplan, 1995) has illustrated the capacity that 'nature' has to aid recovery from mental fatigue, and this concept is extended to the urban forest (Kaplan, 2002). The positive emotions needed to recover from mental fatigue were identified in response specifically to street trees by Sheets and Manzer (1991: 301), who found that 'Our subjects reported more positive feelings when viewing tree-lined city streets; they felt friendlier, more cooperative, less sad and less depressed'. Street trees can have demonstrable effects upon other aspects of human health and wellbeing (Lovasi *et al*., 2008; see O'Brien *et al*., 2010, for a comprehensive review of the health impacts of the urban forest).

Urban green spaces with trees appear to have the potential to be safer than those without – trees may thus be considered to have a safety value. A growing number of studies have begun to challenge the perception that standing roadside trees pose only a threat to drivers, and to assert that trees can, in fact, improve driving safety in some circumstances. The main positive effect here appears to be a reduction in speed resulting from improved landscaping using trees (Naderi, 2003; Dumbaugh, 2005; Wolf and Bratton, 2006; Burden, 2008). Further to this, Wolf (2006: 56) links better driving to improved driver psychology, noting that 'Drivers seeing natural roadside views show lower levels of stress and frustration compared to those viewing built settings.'.

Certain categories of social value are contingent on trees facilitating increased *use* of community spaces. Although there is no published evidence relating directly to street trees, research has correlated the 'greenness' of urban spaces (particularly trees) and reduced crime – in terms of fewer calls to the police and less domestic violence (Kuo *et al*. 1998a; Kuo, 2001, 2003). For example, Kuo (2003: 148, emphasis added) found that:

*The presence of trees and well-maintained grass can transform these no man's lands into pleasant, welcoming, well-used spaces.* ***Vital, well used neighborhood common spaces serve to both strengthen ties among residents and deter crime, thereby creating healthier, safer neighborhoods.*** *... Contact among neighbors and informal surveillance are, in turn, known to be linked to strength of community and levels of crime...*

Burden (2008: 3) also links trees to improved 'security' through increased ownership and surveillance.

*Trees create more pleasant walking environments, bringing about increased walking, talking, pride, care of place, association and therefore actual ownership and surveillance of homes, blocks, neighbourhoods, plazas, businesses and other civic spaces.*

Urban areas with trees appear to have potentially stronger and more stable communities. As with safety value (reduced crime) above, this phenomenon is again linked to increased *use* of community spaces when trees are present and the resultant increased interaction between community members. This relationship is now well established (see Kuo *et al*., 1998b; Kuo, 2003). Schroeder and Ruffolo (1996) (data also analysed in Schroeder *et al*., 2006) highlighted that residents in a Chicago suburb included increased 'sense of community' among the most important benefits of street trees, echoing an earlier finding by Sommer and Sommer (1989). Residential areas with trees have also been correlated to higher property occupancy rates and reduced household 'turnover', suggesting a more stable community (Miller, 2007).

The wider literature on the social and cultural values of trees identifies their historical value – that is, their capacity to connect human generations. Mynors (2002: 4–5) notes:

*the very fact of a tree's longevity, its normal life greatly exceeding that of a human being, means that it is a direct and tangible contact with both past and future. ... very many trees are older than any people now living, or even their parents; and their age provides a link to past ages that is itself of value.*

This category of value is not contingent upon social interaction, but is clearly relational in other respects.

One category of value at the interface of economic and social life is the added value that street trees can bring for businesses, especially those able to utilise tree spaces such as cafes and restaurants (Wolf, 2004, 2005a, 2005b). It appears, for example, that customers travel further to, and pay higher prices for goods in (i.e. *behave differently in* relation to) shops in areas with trees. This is likely also to be the case for small green space areas. Venkatesh (2006) describes the central place of urban parks in the informal economy of poor communities.

Hitchmough and Bonugli (1997), Bonnes *et al*. (2004), Martin *et al*. (2004) and Zhang *et al*. (2007) all suggest the values associated with street trees vary with socio-economic 'status'. Individual knowledge (Kalmbach and Kielbaso, 1979; Bonnes *et al*., 2004), gender (Hitchmough and Bonugli, 1997) and ethnicity/cultural background (Fraser and Kenney, 2000) have all been discussed as further potential influences. However, Flannigan (2005) found that demographic factors had little effect upon attitudes towards street trees among residents in South West England.

## Street tree projects and the generation of social action

The literature described above illustrates and explains the breadth of social values associated with street trees, including the generation of social action. Recent initiatives and projects have sought to apply this, and have begun to generate practical evidence to support the theoretical framework. A report for BBC News (Barford, 2010), covering the Big Tree Plant campaign, highlights how the UK government claims that getting involved in planting trees can make communities happier. The report cites the Trees for Cities Chief Executive stating that community involvement in choosing tree species and planting the trees can have a big impact in deprived areas where urban 'wastelands' can be transformed into accessible community places. This programme builds on the Coalition government's 'Big Society' agenda aimed at helping communities to come together and take responsibility for improving their neighbourhoods (Defra, 2010).

Green Streets projects in the Red Rose Forest, Greater Manchester, and Mersey Forest aim to improve the environmental quality of deprived areas and the quality of life for urban residents. Both the Red Rose Forest and Mersey Forest encompass a growing network of woodlands and green spaces. Local people are given the opportunity to become involved in the design and development of greening schemes, such as tree planting, which further encourages community interaction and a sense of ownership of the schemes. TreeBristol is a local authority body overseeing the city's trees (McEwan, 2010). A centralised mapping and database system highlights potential locations for tree planting that are most cost-effective. Community engagement facilitates people choosing tree species and becoming involved in planting (although the practical difficulties of planting trees in concreted highways can limit the direct involvement of community members in planting), all of which can contribute to long-term commitment to maintenance and care of the trees. In addition, projects such as 'celebration trees' are promoted where family and friends can fund the planting of a tree in memory of a loved one (McEwan, 2010). This project benefitted from having dedicated staff for community engagement, and from partnership working which facilitated application for funding unavailable to individual organisations (Horsey, 2011, pers. comm.).

Newlands, a Forestry Commission-led land regeneration programme, comprises eight developments across the North West. Community involvement is once again an integral part of the programme with partner organisations (e.g. Groundwork) leading engagement activities (including planting sessions with schools) to foster a sense of ownership and pride in the new green areas. At the Brickfields site, the Forestry Commission and Mersey Forest are working together to integrate regeneration of the site with wider activities involving the greening of local streets and linking green spaces and community woodlands.

As the Greenspace Scotland website notes, green spaces 'encourage communities to mix, supporting people in meeting others, making new connections and developing commitment to their locality and identities'. Communities working together to create 'attractive, well-integrated greenspaces' can contribute to the development of stronger and inclusive communities (http://www.greenspacescotland.org.uk/default.asp?page=492). The Central Scotland Green Network also emphasises the role of green networks in the creation of stronger communities while the Glasgow and Clyde Valley Green Network (GCVGN) incorporates a number of regional 'greenspace teams' working with local communities to regenerate neighbourhood open spaces.

All the examples above involve some element of environmental 'education', but individuals and communities can also be encouraged to engage with the outdoor environment and contribute to scientific understanding of the natural world. Indeed, one promising area for engagement with street trees is citizen science, or the gathering of scientific data by volunteers usually towards a collective end that has more impact than would individual efforts. If we consider citizen science as a form of social action we can see that street trees, or trees in residential areas, have the potential to catalyse such action.

Citizen science projects linked to street trees certainly contribute to the 'bigger picture'. London's Natural History

Museum (NHM) is currently running an 'urban trees survey' which relies on members of the public sending in reports of street trees. It encourages such records with the plea: 'Take part in our survey so we can build a picture of what trees are growing where and find out how the tree population is changing. ...We need you to take part because you have access to the neighbourhoods and gardens we're interested in'. There is some evidence that the existence of the survey leads some participants to see green spaces as linked in to the street trees. For example, although the survey explicitly excludes woodlands, one question posted on the bulletin board asks: 'I would like to include the trees in a nearby cemetery in the NHM survey. There are hundreds and I want to do this only if it is useful. I also want to know if anyone else is including them.' (http://www.nhm.ac.uk/natureplus/thread/2118?tstart=0).

## Discussion and conclusions

Green networks have risen up the planning agenda speedily, encompassing nearly every natural and semi-natural feature of the urban landscape on their way. However, during this rise the relative contributions of the distinct components of green networks have been rather swept aside. Street trees, for example, appear not generally to be perceived as a major element, and feature only weakly in British planning policies which largely fail to adequately acknowledge their values.

Given that community engagement is likely to be essential for the effective expansion and improvement of green networks, it is essential to try to understand how communities engage with them. Some initiatives, such as the GCVGN, are attempting to achieve this; however, there is virtually no relevant evidence nor much experience, and so our understanding remains very unclear. It might be that some lessons might be drawn from other established networks, such as long-distance footpaths or cycle routes. Anecdotally, our own experiences may lead us to conclude that people do engage with these networks by, for example, repeated use of sections of them in an attempt to complete the whole. There are, however, no prominent attempts to discover how green networks might learn from this experience, and no clear evidence that there is anything to learn! Currently, perhaps the best assumption is that green networks will be engaged with primarily at the level of (through) their individual components. How can this engagement become engagement with the network?

Our paper has brought together considerable evidence to illustrate how street trees, and green spaces, can generate social action, which, although perhaps *ad hoc*, can in turn lead to stronger communities. This might transform into social action around a wider network in a number of ways. First, it may be that local-scale interest groups and 'societies' are intrinsically more likely to evolve from within stronger communities. These groups could, of course, be very varied in their focus, but environmental and wildlife groups are particularly common and such groups may well develop an interest beyond their 'own' street trees towards the wider environmental context and network, and the issues they face. There is a literature on the development and role of 'friends' groups, especially relating to public resources such as parks and libraries, from which lessons could be learned here. Second, social interaction in urban spaces with trees, especially newly planted spaces, is likely to feature conversation about and attention on the trees themselves. This might engender an increased recognition not only of the values and benefits of trees but also more general environmental awareness. Trees can bring greater awareness of seasonal change to an urban street with few other natural signs.

It is likely that social action around street trees can also be transformed into wider social action by external inputs. For example, street trees require regular maintenance and with some community engagement this could be transformed into opportunities to foster environmental knowledge and to communicate about the wider network of which the specific trees are a part. As noted above, another strong opportunity to achieve this transformation is through citizen science. Cooper *et al.* (2007) draw attention to this potential in what they call residential ecosystems (i.e. urban and suburban areas). They propose citizen science as a way to recruit and motivate citizens, and achieve conservation decisions at a cumulative and effective scale. While their arguments are applied particularly to private land such as gardens, they are highly relevant for street trees. Although street trees are usually a public resource, to residents of the streets where they occur, they can feel more personal. Citizen science can draw in data (which is a recognised gap in urban forest management), strengthen connections and engagement, and potentially help citizens to see 'their' street trees as part of a larger whole. Although this should only be treated as a hypothesis at this stage, there is some evidence to support it.

Street trees can open up many opportunities for environmental volunteering, which can have many social benefits, including increasing physical and mental wellbeing and providing opportunities for social interaction (O'Brien *et al.*, 2008, Bell *et al.*, 2010). These activities could easily build awareness of green networks from smaller engagement around street trees as Lawrence and Turnhout (2010) identify wanting to contribute to the bigger picture, or understanding the whole, as one of two main strands of motivation for such volunteering common across many groups and cultures.

We are not seeking to claim that street trees are *per se* better at 'pulling people in' to green networks than other components such as parks or rivers. However, they can clearly have particular social values, can often be in close proximity to people's homes so perhaps in their more immediate thoughts, and their potential is vastly underestimated. They may be of chief importance in some areas, such as those which are green space poor and crowded (i.e. where there is little available space *per se* for green network improvement or expansion). In such circumstances, a small number of trees on a packed urban street, perhaps as part of a 'traffic-calming' redesign scheme, could not only deliver some environmental and safety benefits but also have a potentially transformative impact on the street's community: creating 'space' within it for engagement with green networks. This may especially be the case where some street trees already exist. These could (should!) be celebrated, measured, mapped, maintained and talked about by their local community members.

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## References

BARFORD, V. (2010). Do trees on the streets make people happy? *BBC News Magazine*, 6 December. [Online] Available at: http://www.bbc.co.uk/news/magazine-11889768 [Accessed 10/12/10].

BELL, S., HAMILTON, V., MONTARZINO, A., ROTHNIE, H., TRAVLOU, P. AND ALVES, S. (2008). *Greenspace and Quality of Life: A critical literature review*. Greenspace Scotland, Stirling.

BELL, S., MARZANO, M. AND PODJED, D. (2010). Inside monitoring: a comparison of bird monitoring groups in Slovenia and the United Kingdom. *In:* Lawrence, A. (ed.) *Taking Stock of Nature*. Cambridge University Press, pp. 232–250.

BONNES, M., CARRUS, G. BONAIUTO, M. FORNARA, F. AND PASSAFARO, P. (2004). Inhabitants' environmental perceptions in the city of Rome within the framework for urban biosphere reserves of the UNESCO Programme on Man and Biosphere. *Annals of the New York Academy of Sciences* **1023**, 175–186.

BORST, H.C., DE VRIES, S.I., GRAHAM, J.M.A., VAN DONGEN, J.E.F., BAKKER, I. AND MIEDEMA, H.M.E. (2009). Influence of environmental street characteristics on walking route choice of elderly people. *Journal of Environmental Psychology* **29**, 477–484, 1–8.

BORST, H.C., MIEDEMA, H.M.E., DE VRIES, S.I., GRAHAM, J.M.A. AND VAN DONGEN, J.E.F. (2008). Relationships between street characteristics and perceived attractiveness for walking reported by elderly people. *Journal of Environmental Psychology* **28**, 353–361.

BURDEN, D. (2008). *Benefits of Urban Street Trees*. Urban Forest Ecosystems Institute Discussion Paper. [Online] Available at: http://www.ufei.org/files/pubs/22BenefitsofUrbanStreetTrees.pdf

CHEN, W.Y. AND JIM, C.Y. (2008). Assessment and valuation of the ecosystem services provided by urban forests. *In:* Carreiro, M.M. Song, Y.C. and Wu, J. (eds.) *Ecology, Planning, and Management of Urban Forests*. Springer, New York, 53–83.

CLG [DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT] (2002). *Planning for Open Space, Sport and Recreation: Planning Policy Guidance 17* (PPG 17). Department for Communities and Local Government, London.

COHEN, D.A., MCKENZIE, T.L., SEHGAL, A., WILLIAMSON, S., GOLINELLI, D. AND LURIE, N. (2007). Contribution of public parks to physical activity. *American Journal of Public Health* **97**(3), 509–514.

COLEY, R.L., SULLIVAN, W.C. AND KUO, F.E. (1997). Where does community grow?: the social context created by nature in urban public housing. *Environment and Behavior* **29**, 468–494.

COOPER, C.B., DICKINSON, J. PHILLIPS, T. AND BONNEY, R. (2007). Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society* **12**(2), 11. [Online] Available at: http://www.ecologyandsociety.org/vol12/iss2/art11/

CROUCHER, K., MEYERS, L. AND BRETHERTON, J. (2007). *The links between greenspace and health: a critical literature review*. Greenspace Scotland, Stirling.

DANDY, N. (2010). *The social and cultural values, and governance, of street trees*. Forest Research, Farnham.

DE VRIES, S., CLASSEN, T., EIGENHEER-HUG, S., KORPELA, K., MAAS, J., MITCHELL, R. AND SCHANTZ, P. (2011). Contributions of natural environments to physical activity. Theory and evidence base. *In:* Nillson, K., Sangster, M., Gallis, C., Hartig, T., de Vries, S., Seeland K. and Schipperijn J. (eds.) *Forests, Trees and Human Health*. Springer, Berlin, pp. 205–244.

DEFRA. (2010). *The Big Tree Plant: new partnership to plant one million trees.* [Online] Available at: http://ww2.defra .gov.uk/news/2010/12/02/tree-plant/ [Accessed 07/02/11].

DUMBAUGH, E. (2005). Safe streets, livable streets. *Journal of the American Planning Association* **71**(3), 283–300.

DUNNETT, N., SWANWICK, C. AND WOOLLEY, H. (2002). *Improving Urban Parks, Play Areas and Green Spaces.* Department for Transport, Local Government and the Regions, London, 214pp.

ELLIS, C.D., LEE, S. AND KWEON, B. (2006). Retail land use, neighbourhood satisfaction and the urban forest: an investigation into the moderating and mediating effects of trees and shrubs. *Landscape and Urban Planning* **74**, 70–78.

ELMENDORF, W. (2008). The importance of trees and nature in community: a review of the relative literature. *Arboriculture & Urban Forestry* **34**(3), 152–156.

FLANNIGAN, J. (2005). An evaluation of residents' attitudes to street trees in southwest England. *Arboricultural Journal* **28**, 219–241.

FOREST RESEARCH (2010). *Benefits of green infrastructure. Report to Defra and CLG*. Forest Research, Farnham.

FRASER, E.D.G. AND KENNEY, W.A. (2000). Cultural background and landscape history as factors affecting perceptions of the urban forest. *Journal of Arboriculture* **26**(2), 106–113.

GILES-CORTI, B., BROOMHALL, M.H., KNUIMAN, M., COLLINS, C., DOUGLAS, K., NG, K., LANGE, A. AND DONOVAN, R. (2005). Increasing walking: how important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* **28**(2), 169–176.

GREENSPACE SCOTLAND (2008). *Greenspace quality: a guide to assessment, planning and strategic development*. Greenspace Scotland and Glasgow & Clyde Valley Green Network Partnership. 53 pp.

HITCHMOUGH, J.D. AND BONUGLI, A.M. (1997). Attitudes of residents of a medium sized town in South West Scotland to street trees. *Landscape Research* **22**(3), 327–337.

HORSEY, R. (2011). Personal communication via telephone from Russell Horsey, Senior Arboricultural Officer, Bristol City Council, and TreeBristol project, 24 February 2011.

KALMBACH, K.L. AND KIELBASO, J.J. (1979). Resident attitudes towards selected characteristics of street tree plantings. *Journal of Arboriculture* **5**(6), 124–129.

KAPLAN, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology* **15**, 169–182.

KAPLAN, S. (2002). Some hidden benefits of the urban forest. *In:* Konijnendijk, C.C. and Hoyer, K.K. (eds.) *Forestry Serving Urbanised Societies*, Abstract book. IUFRO European Regional Conference, in collaboration with EFI, Copenhagen, 27–30 August, 2002, pp. 221–231.

KAPLAN, R. AND KAPLAN, S. (1989). *Experience of nature: A psychological perspective*. Cambridge University Press, New York.

KONIJNENDIJK, C.C. (2008). *The Forest and the City: The cultural landscape of urban woodland*. Springer, Netherlands.

KUO, F.E. (2001). Coping with poverty: Impacts of environment and attention in the inner city. *Environment and Behavior* **33**, 5–34.

KUO, F.E. (2003). The role of arboriculture in a healthy social ecology. *Journal of Arboriculture* **29**(3), 148–155.

KUO, F.E., BACAICOA, M. AND SULLIVAN, W.C. (1998A). Transforming inner-city landscapes: trees, sense of safety, and preference. *Environment and Behavior* **30**, 28–59.

KUO, F.E., SULLIVAN, W.C., COLEY, R.L. AND BRUNSON, L. (1998B). Fertile ground for community: inner-city neighborhood common spaces. *American Journal of Community Psychology* **26**(6), 823–851.

KWEON, B.S., SULLIVAN, W.C. AND WILEY, A.R. (1998). Green common spaces and the social integration of inner-city older adults. *Environment and Behavior* **30**, 832–858.

LAWRENCE, A. AND TURNHOUT, E. (2010). Personal meaning in the public sphere: The standardisation and rationalisation of biodiversity data in the UK and the Netherlands. *Journal of Rural Studies* **26**, 353–360.

LCR (LEEDS CITY REGION) (2010). *Green Infrastructure Strategy*.

LOVASI, G.S., QUINN, J.W., NECKERMAN, K.M., PERZANOWSKI, M.S. AND RUNDLE, A. (2008). Children living in areas with more street trees have lower prevalence of asthma. *Journal of Epidemiology and Community Health* **62**, 647–649.

LOVELL, R., O'BRIEN, L. AND OWEN, R. (2010). Review of the research evidence in relation to the role of trees and woods in formal education and learning. [Online] Available at: http://www.forestry.gov.uk/pdf/Education_and_learning_research_review_2010.pdf/ [Accessed 10/11/10].

MCEWAN, G. (2010). The wooded city. *Horticulture Week*, 19 November, 18–19.

MCPHERSON, E.G., SIMPSON, J.R., XIAO, Q. AND WU, C. (2010). Million trees Los Angeles canopy cover and benefit assessment. *Landscape and Urban Planning* **99**(1), 40–50.

MARTIN, C.A., WARREN, P. AND KINZIG, A. (2004). Neighborhood socioeconomic status is a useful predictor of perennial landscape vegetation in residential neighborhoods and embedded small parks in Phoenix, AZ. *Landscape and Urban Planning* **69**, 355–368.

MILLER, K. (2007). *ANJEC in the City: The Benefits of City Trees*. Association of New Jersey Environmental Commissions (ANJEC). [Online] Available at: http://www.anjec.org/pdfs/city-treebenefits.pdf [Accessed 02/09/09].

MOSELEY, D. AND MARZANO, M. (IN REVIEW) *Green networks and people: a review of research and practice in the analysis and planning of multi-functional green networks*. Forest Research and Scottish Natural Heritage, 93pp.

MYNORS, C. (2002). *The Law of Trees, Forests and Hedgerows*. Sweet & Maxwell, London.

NADERI, J.R. (2003). Landscape design in the clear zone: The effects of landscape variables on pedestrian health and driver safety. *In: Transportation Research Board, 82nd Annual Conference Proceedings*. Transportation Research Board, Washington D.C., pp. 119–130.

NATURAL ENGLAND (2009). *Green Infrastructure Guidance*. London, 97 pp.

O'BRIEN, L., TOWNSEND, M. AND EBDEN, M. (2008). *I like to think when I'm gone I will have left this a better place: environmental volunteering: motivations, barriers and benefits.* Report to the Scottish Forestry Trust and Forestry Commission.

O'BRIEN, L., WILLIAMS, K. AND STEWART, A. (2010). Urban health and health inequalities and the role of urban forestry in Britain: A review. [Online] Available at: http://www.forestry.gov.uk/fr/INFD-83EHVX [Accessed 10/11/10].

PIKORA, T., GILES-CORTI, B., BULL, F., JAMROZIK, K. AND DONAVAN, R. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. *Social Science and Medicine* **56**, 1693–1703.

RAVENSCROFT, N. AND MARKWELL, S. (2000). Ethnicity and the integration and exclusion of young people through urban park and recreation provision. *Managing Leisure* **5**, 135–150.

READ, D.J., FREER-SMITH, P.H., MORISON, J.I.L., HANLEY, N., WEST, C.C. AND SNOWDON, P. (EDS.) (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*. The Stationery Office, Edinburgh.

SCHROEDER, H., FLANNIGAN, J. AND COLES, R. (2006). Residents' attitudes toward street trees in the UK and U.S. communities. *Arboriculture & Urban Forestry* **32**(5), 236–246.

SCHROEDER, H. AND RUFFOLO, S.R. (1996) Householder evaluations of street trees in a Chicago suburb. *Journal of Arboriculture* **22**(1), 35–43.

SCOTTISH GOVERNMENT (2008). *Planning Advice Note (PAN 65) Planning and Open Space.* Scottish Government, Edinburgh, 28 pp.

SCOTTISH GOVERNMENT (2009). *National Planning Framework 2.* Scottish Government, Edinburgh, 131 pp.

SCOTTISH GOVERNMENT (2010). *Scottish Planning Policy.* Scottish Government, Edinburgh, 56 pp.

SEELAND, K., DÜBENDORFER, S. AND HANSMANN, R. (2009). Making friends in Zurich's urban forests and parks: The role of public green space for social inclusion of youths from different cultures. *Forest Policy and Economics* **11**, 10–17.

SHEETS, V.L. AND MANZER, C.D. (1991). Affect, cognition, and urban vegetation: some effects of adding trees along city streets. *Environment and Behavior* **23**(3), 285–304.

SOMMER, R. AND SOMMER, B. (1989). The factor structure of street tree attributes. *Journal of Arboriculture* **15**, 243–246.

STEWART, A., LAWRENCE, A. AND MOLTENO, S. (2010). Social benefits. *In:* J. Claridge, C. Foster and T. Hutchings (eds.) *Benefits of green infrastructure: Report to Defra and CLG*. Forest Research, Farnham, pp. 35–69.

STEWART, A. AND O'BRIEN, L. (2010). Inventory of social evidence and practical programmes relating to trees, woods and forests and urban/peri-urban regeneration, place-making and place-shaping. [Online] Available at: http://www.forestry.gov.uk/pdf/place_and_communities_inventory_report_Oct2010.pdf/$FILE/place_and_communities_inventory_report_Oct2010.pdf [Accessed 17/11/10].

SULLIVAN, W.C., KUO, F.E. AND DEPOOTER, S.F. (2004). The fruit of urban nature: vital neighbourhood spaces. *Environment and Behavior* **36**, 678–700.

TYRVÄINEN, L., MÄKINEN, K. AND SCHIPPERIJN, J. (2007). Tools for mapping social values of urban woodlands and other green areas. *Landscape and Urban Planning* **79**, 5–19.

TZOULAS, K., KORPELA, K., VENN, S., YLI-PELKONEN, V., KA MIERCZAK, A., NIEMELA, J. AND JAMES, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning* **81**(3), 167–178.

VENKATESH, S.A. (2006). *Off the Books: The underground economy of the urban poor*. Harvard University Press, London.

WELCH, J.M. (1994). Street and park trees of Boston: A comparison of urban forest structure. *Landscape and Urban Planning* **29**(2–3), 131–143.

WELDON, S. AND BAILEY, C. (2007). *New pathways to health and well-being: Summary of research to understand and overcome barriers to accessing woodland*. Summary report. Forestry Commission Scotland.

WILLIAMS, K. (2002). Exploring resident preferences for street trees in Melbourne, Australia. *Journal of Arboriculture* **28**(4), 161–170.

WOLF, K. (2004). Trees and business district preferences: A case study of Athens, Georgia, U.S. *Journal of Arboriculture* **30**(6), 336–346.

WOLF, K. (2005A). Trees in the small city retail business district: comparing resident and visitor perceptions. *Journal of Forestry* **103**, 390–395.

WOLF, K. (2005B). Business district streetscapes, trees, and consumer response. *Journal of Forestry* **103**, 396–400.

WOLF, K. (2006). Roadside urban trees: Balancing safety and community values. *Arborist News*, December, 56–7.

WOLF, K. AND BRATTON, N. (2006). Urban trees and traffic safety: Considering U.S. roadside policy and crash data, *Arboriculture & Urban Forestry* **32**(4), 170–179.

WOOLEY, H., ROSE, S., CARMONA, M. AND FREEDMAN, J. (2004). *The value of public space: How high quality parks and public spaces create economic, social and environmental value*. CABE Space, London.

ZHANG, Y., HUSSAIN, A., DENG, J. AND LETSON, N. (2007). Public attitudes toward urban trees and supporting urban tree programs. *Environment and Behavior*, **39**(6), 797–814.

# Promoting wellbeing through environment: the role of urban forestry


## Abstract

Many of us feel intuitively that having access to nature in urban environments is important for our quality of life. The evidence base supporting this claim has grown considerably in recent years, with high profile studies highlighting the links between access to greenspace/having views of nature and health and wellbeing. Physical activity in green environments is increasingly seen as a valuable treatment for mental health problems and a buffer against the development of depression and anxiety disorders. This paper explores the existing research and theory on the value of nature in the built environment for the wellbeing of city-dwellers, focusing on the role of urban forestry. It also raises questions about what we still have to learn about these less tangible benefits of urban trees and woodlands.



**Keywords:**

green exercise, mental health, restorative environments, street trees, urban greenspace


## Introduction

Issues of mental health and wellbeing have become increasingly important in developed countries, where depression and anxiety rates have risen despite increases in living standards and economic growth. Recent years have seen growth in research on the impact of the physical environment on mental health and wellbeing, and trees and woodland are now being promoted as 'nature's health service' (O'Brien, 2005).

This paper provides an overview of the research on the connection between nature and wellbeing, with a focus on urban woodland and trees in the built environment. Evidence on the spatial associations between greenspace and health, and on the benefits of 'green exercise' will be examined. The discussion then moves on to the theoretical basis of these relationships and introduces the field of restorative environments research. The specific role of forests, woodlands and trees in the built environment in promoting wellbeing is then explored, drawing from the international literature on restorative environments. In addition to examining the existing evidence base, the paper also discusses some of the gaps in the research and suggests problems warranting further study.

## Spatial associations between greenspace and health

Various studies have demonstrated associations between access to local greenspace and population health and wellbeing. People living in areas with high quantities of greenspace have been found to have better health, as measured using both self-report data from surveys and records of morbidity and mortality rates (Maas *et al*., 2006, 2009; Mitchell and Popham, 2007, 2008). These associations between greenspace availability and population health are seen even when socioeconomic factors are controlled for; it seems this is not a spurious association arising out of an interaction between the well-documented health inequalities between the rich and poor and a selection effect where those on higher incomes might be gravitating towards areas with plenty of greenspace. In fact, large-scale studies on English and Dutch populations have found that it is those in the lowest income groups that benefit the most from having greenspace near their home (Maas *et al*., 2006; Mitchell and Popham, 2008).


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The level of urbanity also seems to affect the relationship between greenspace and health. In urban areas more greenspace is associated with better health regardless of income levels, but in both rural and suburban areas with high income levels there is no significant association (Mitchell and Popham, 2007). It has been suggested that this pattern may be due to the fact that outside the urban area the majority of high income households have their own garden and therefore they may rely less on public greenspace. One unexpected finding in this study was that there was an inverse relationship between greenspace availability and health found in the case of low income suburban areas. It may be that deprived peripheral housing estates have a larger proportion of low quality and inaccessible greenspaces. The authors suggest that either 'the health benefits of poor quality greenspace, albeit in large quantities, are not sufficient to negate the health problems of the resident population; or poor quality greenspace is actually detrimental to health' (Mitchell and Popham, 2007:682).

Researchers have also looked at how the prevalence of different types of health complaints varies with greenspace availability. On the whole the strongest negative associations are with mental health problems like anxiety and depression, diseases where stress is a risk factor, and on respiratory complaints (Mitchell and Popham, 2008; Maas *et al*., 2009). The link between greenspace and respiratory complaints seems natural given the positive effect of vegetation on air quality. But how do we explain the associations between greenspace and other health complaints, particularly mental health issues?

When considering the potential causal pathways that may link green environments and health, there are two prime suspects. The first is physical activity. Perhaps having more greenspace near home encourages people to be more physically active, and this has a positive influence on their physical and mental health. The evidence here appears to be mixed. One study from the Netherlands factored in physical activity levels and found that they did not explain the link between greenspace and health (Maas *et al*., 2008). Another study from Australia using similar methods found that levels of physical activity accounted for the correlation between greenspace and physical health, but not mental health (Sugiyama *et al*., 2008). Therefore it seems that, particularly for mental health and wellbeing, effects on physical activity levels alone do not sufficiently explain the patterns that have been found.

## Green exercise

The other possibility is that there is an independent effect of the physical environment itself. Research into green exercise has explored the synergistic effects of physical activity and the environment in which activity takes place. Green exercise refers to physical activity outdoors in a primarily green environment and includes activities like walking, hiking, running, cycling, gardening and nature conservation. Such studies on green exercise have demonstrated that the environment does affect the psychological outcomes of exercise, with views of pleasant scenes, particularly of a green environment, having the greatest positive effect (Pretty *et al*., 2005). Attempts have been made to define dose-response curves for green exercise, and these indicate that large benefits can be gained from even brief five-minute spells of green exercise (Barton and Pretty, 2010). Those with poor mental health appear to gain more in terms of improvements in mood and self-esteem as a result of green exercise than those with good mental health (Roe and Aspinall, 2011), and green exercise projects are increasingly seen as a valuable form of treatment for mental health problems. Various evaluations of health walks programmes, green gyms, nature conservation projects, forest schools and horticultural therapy have supported the view that regular contact with nature has a measurable positive effect on participants' subjective wellbeing and coping resources over the longer term (Wilson *et al*., 2008). However, it is important to recognise the other factors that may contribute to these benefits; the social context of organised green exercise programmes and the acquisition of new skills and knowledge are also likely to have a positive impact on self-esteem.

## Restorative environments

A large body of research exists on the psychological benefits of passive interactions with natural environments, and even from viewing nature through windows and in photographs and art. This 'restorative environments' research focuses on the independent effect of the perception of the physical environment. The term restorative environment is used to describe places that promote psychological 'restoration' processes. In this context restoration is defined as 'the process of recovering physiological, psychological and social resources that have become diminished in efforts to meet the demands of everyday life' (Hartig, 2007:164). The rest of this paper examines the research on this restorative effect of nature.

A large number of studies have investigated the immediate physiological and psychological responses to different environments, and have found that exposure to natural environments has a number of benefits over built environments lacking natural features. Positive effects of nature experience on physiological indicators including blood pressure, heart rate, brainwave patterns, muscle tension, stress hormone levels and even immune system functioning have been demonstrated (Hartig *et al*., 2003; Park *et al*., 2010). In terms of the immediate cognitive and affective responses, exposure to natural environments has repeatedly been shown to improve ability to direct attention and maintain concentration, and to improve mood, particularly in terms of reducing negative emotions like feelings of stress, anxiety and frustration (Hartig *et al*., 2003; Hartig, 2007). These responses have been seen not just when people directly experience an outdoor green environment, but also when viewing them through windows and even in videos and photographs. Again, the greater an individual's need for restoration (i.e. the more stressed and/or fatigued they are) the more they benefit from exposure to a natural environment (Ottosson and Grahn, 2008).

Much of this research has been conducted by environmental psychologists in Scandinavian countries and the USA, but restorative environments have recently been gaining interest all over the world and attracting interest from researchers in a range of academic disciplines other than psychology, including urban planning, landscape architecture and health research. Similar positive outcomes for wellbeing have emerged in populations the world over. Two theoretical frameworks arose to try to explain the mechanisms by which these benefits arise: stress recovery theory and attention restoration theory. Each emphasises a different process of psychological restoration, and the theories are for the most part considered by researchers to be complementary rather than competing.

## Stress recovery

This theoretical framework promotes a functional-evolutionary perspective on restoration, referred to variously as stress recovery, psychophysiological stress reduction and psychoevolutionary theory. In this case the costs of stress responses to threats and subsequent needs for restoration are emphasised. Stress recovery theory proposes that rapid-onset emotional reactions are a critical part of the initial response to threats, mobilising the body's physiological systems and motivating 'fight or flight' behaviour. However, the costs of this stress response are high (strong negative emotions and energy-sapping physiological arousal), so there is a need for restoration to occur when the threat has passed. It is proposed that we evolved a propensity to respond both emotionally and physically in a strong positive way to unthreatening natural environments as an adaptive mechanism to allow fast and effective recovery from the stress response, and that modern humans retain this adaptation. It is thought that this 'prepared response' occurs in natural environments and not built environments because we have spent millions of years evolving in natural environments and adapting to them, but have only lived in permanent settlements for a very short time in evolutionary terms (Ulrich, 1993).

The discussion of what makes a natural environment restorative from the perspective of stress recovery theory draws on evolutionary theories of landscape aesthetics. These suggest that features of a stress-reducing environment include those which signal a positive human habitat through 'affordances' such as safe drinking water, food and shelter and also those which allow open views of the landscape in conjunction with more enclosed, private spaces of refuge (Ulrich, 1993).

## Attention restoration

This framework explains the restorative benefits of nature through cognitive rather than psychophysiological processes. In this theoretical framework, benefits to mood and reduction in feelings of stress and anxiety are linked to an overarching benefit to information processing capabilities. Attention Restoration Theory (ART) rests on the concept that we have a finite capacity for focusing our attention, which becomes depleted with mental effort, causing a state of 'attentional fatigue' and a concomitant reduction in mental performance. It is argued that maintaining directed attention requires blocking out unwanted distractions from the environment, and for this to happen an inhibitory mechanism is needed. Exercising this mechanism uses energy and depletes attentional resources. When our ability to direct attention has become depleted, restoration through rest, sleep or relaxation in a supportive environment must occur before performance can rise again (Kaplan, 1995). Natural environments are held to be most conducive to attention restoration, but effective restoration need not be confined to these. According to ART this state of mental fatigue has negative effects not just on performance in tasks requiring focus and concentration, but also on moods and behaviour – with irritability, frustration, impatience, depression, impulsivity and social irresponsibility implicated as consequences of attentional fatigue (Kaplan, 1995).

ART proposes four components that contribute towards an environment's potential to promote attention restoration – 'being away', 'fascination', 'extent' and 'compatibility' (see Box 1). ART holds that natural environments often offer high levels of each of these components for restoration, more so than most urban environments, and this is the reason for the patterns of variation in restoration between the natural and urban. Perception of high levels of these qualities has been linked to objectively measured restoration benefits (Berto, 2005; Chang *et al.*, 2008). Other researchers have developed these components and used them as a basis for measuring the perceived restorative potential of environments (Hartig *et al.*, 1997).

**Box 1. ART's four components of restorative environments**

1) *Being away* – This relates to achieving a sense of distance (at least psychologically, if not physically too) from demands and drains on directed attention.

2) *Fascination* – This describes surroundings which attract interest and draw the attention without any effort on the part of the viewer. A distinction is made between 'hard' and 'soft' forms of fascination. Soft fascination, where involuntary attention is drawn in a manner that still allows room for self-reflection during the experience, is thought to be particularly important for attention restoration.

3) *Extent* – For effective restoration the environment must be coherent and comprehensive enough to feel like a world to itself. 'It must provide enough to see, experience, and think about so that it takes up a substantial portion of the available room in one's head' (Kaplan, 1995:173).

4) *Compatibility* – This relates to the fit between the individual's purposes and inclinations for behaviour in the environment and the behaviour that the environment permits or demands. A compatible environment is one in which it is appropriate to behave in a way that feels comfortable or natural, and which allows desired activities to be carried out with ease.

## The role of forest and woodland in psychological restoration

Trees appear to play a significant part in promoting restoration processes. Woodlands and forests are commonly reported as the most desired environment for relaxing and recovering from stress and sustained mental effort (Grahn and Stigsdotter, 2003; Hansmann, *et al.*, 2007). They also feature highly in studies of favourite places, thought to allow a view into the places people choose for the purposes of regulating their emotions (Korpela *et al.*, 2008). On the other hand forests can also be perceived as a threatening environment. This connotation of forest environments is deeply embedded in our culture – the fairytales we grow up hearing are steeped in imagery of forests as foreboding places, and media reports of attacks in wooded areas are common. Many people report feeling unsafe in urban woodlands, with women often feeling less safe than men (Ward Thompson *et al.*, 2008).

Most studies measuring restorative outcomes to investigate the psychological effects of different environments have made broad comparisons between 'natural environments' and 'built environments'. It should be noted that the term 'natural environment' is used in a broad manner in the restorative environments literature to encompass all environments where buildings and human artefacts do not dominate. Few distinctions are therefore made between green environments with a high level of human influence (e.g. parks, plantation forestry and agricultural landscapes) and those which are more natural in an ecological sense, like wilderness areas, ancient woodlands and semi-natural greenspace. Little research has been specifically focused on the restorative effect of forest and woodland environments, although these commonly feature as examples of natural environments. An exception to this is a body of research from Japan into the benefits of the activity known as shinrin-yoku.

Shinrin-yoku is defined as 'taking in the forest atmosphere or forest bathing' (Tsunetsugu *et al.*, 2010:27). This term was coined by the Forest Agency of Japan in the 1980s and has since become a recognised and popular activity for relaxation and stress management. The research on shinrin-yoku differs from that on restorative environments in the West in that it emphasises the olfactory element of the forest experience. This aspect has been neglected in other studies, which have mainly focused on the visual aspects of environmental perception, and in a few cases the auditory experience. Shinrin-yoku is conceived as a form of 'natural aromatherapy' where the inhalation of wood essential oils (phytoncides) is considered as the prime pathway to the relaxation effect, although beautiful scenery, tranquillity and fresh air are still recognised as important aspects of the positive forest experience (Li, 2010:9).

Field experiments across Japan have found that subjects taking part in short walks in both a forest and a city displayed different physiological responses to the different environments. The forest walk produced significantly lower concentrations of the stress hormone cortisol in participants' saliva, lower pulse rate and blood pressure, lower sympathetic nerve activity (associated with the 'fight or flight' response), and greater parasympathetic nerve activity (associated with relaxation, the 'rest and digest' response) (Park *et al.*, 2010). Large reductions in levels of adrenaline and noradrenaline (hormones associated with stress and the sympathetic nervous system), and in the blood-glucose levels of diabetes sufferers have also been found after forest bathing (Li, 2010). Other studies have demonstrated a positive and prolonged effect of shinrin-yoku on immune system functioning. A forest bathing trip (lasting 3 days and 2 nights) resulted in significant improvements in various indicators of immune system functioning, including the number and activity of natural killer (NK) cells, and levels of anti-cancer proteins in the blood (Li, 2010). NK cell activity remained elevated well after the trip had finished, to the point where testing 30 days afterwards showed that in male subjects the difference from the baseline measurements was still significant. In female subjects the difference was still significant after 7 days but not after 30 days, although average levels were still higher than they had been before the trip. When forest bathing trips were compared with physiological measures taken on a city sightseeing trip (of the same duration and with the same amount of walking) no change in NK cell activity was found. It is known that stress can have a dampening effect on the immune system, but these studies are the first to demonstrate that reductions in stress as a result of walking in a natural environment has a measurable and long-lasting effect on immune functioning. What is not known is how shorter visits to forests affect the immune system, and whether the longer-term elevation in immune activity seen as a result of weekend forest trips can also be achieved with regular short visits.

Aside from the objective physiological effects of shinrin-yoku, similarly positive effects on mood have also been demonstrated. Significant differences have been found between the changes in mood states on short forest and city walks, with forest walks consistently producing positive effects in terms of reducing ratings of tension and anxiety, depression and dejection, anger and hostility, fatigue and confusion, and in boosting feelings of vigour. Conversely, the city walks had a negative influence on all of these mood measures (Park *et al*., 2010). Similar positive effects on mood were previously found by Morita *et al*. (2007), who compared mood ratings made on forest visit days with control days (days off work where a forest was not visited). Participants' moods were better on the forest days, regardless of whether participants took part in exercise or their own favourite activities on the control days. Again, the higher the baseline stress level, the greater were the positive changes in mood.

Overall, the body of work on shinrin-yoku provides strong support for the positive psychological and physiological effects of the forest environment. The question is whether these findings can be generalised for populations where appreciation of trees and forests is perhaps less culturally embedded. Also, if smelling and inhaling wood essential oils does contribute towards the restorative effects of shinrin-yoku, do the essential oils from the native tree species of other regions or countries have a similar effect?

## Variation in the restorative quality of forest and woodland environments

So far this paper has discussed forest and woodland environments in broad terms. The research on shinrin-yoku and studies measuring levels of actual restoration in natural environments provides evidence on the benefits of visiting forests, but it contributes little to our understanding of how restorative quality may vary in different types of woodland, at different times of the year, and with different management techniques. Studies aiming to measure 'perceived restorativeness' rather than actual outcomes of restoration offer some hope in this respect. Environmental psychologists have developed several psychometric scales to measure perceived restorative quality. Most of these scales are based on the components of restorative environments according to Attention Restoration Theory – the feelings of 'being away', opportunity for 'fascination', the 'extent' of the environment and its 'compatibility' with intended or preferred behaviour. The most commonly applied ART-based scale is the Perceived Restorativeness Scale (Hartig *et al*., 1997), which exists in various versions. Other scales have been designed to measure restorative potential based on users' perceptions of their own restoration outcomes there, and these focus not just on attention restoration but also on stress recovery responses (Han, 2007; Korpela *et al*., 2008). All of these psychometric scales are administered in a questionnaire format, where participants rate their agreement with various statements. Perceived restorativeness ratings on such scales have been shown to relate to measured restoration outcomes, supporting their validity for use in assessing the restorative quality of different environments (Hartig *et al*, 1997; Chang *et al*., 2008).

Studies employing such scales have typically found forest environments to be high in restorative quality, as judged in visual terms from photographs (Peron *et al*., 2002; Han, 2007; Vassiljev *et al*., 2007). The evidence regarding different types of forest is mixed. Coniferous forest was rated higher in perceived restorativeness than deciduous forest in Han's (2007) study using ratings from American students. In contrast, Vassiljev *et al*. (2007), who have conducted the only study of this kind to evaluate a comprehensive array of vegetation types, found mature (thinned) deciduous woodland highest in restorative quality of all the vegetation types studied, for both summer and winter conditions. Deciduous stands (both mature and young) were on average rated higher in restorativeness than the coniferous stands by their Estonian participants, and among the coniferous scene examples pines were rated higher than spruce stands. Apparent ease of movement and smoothness of ground cover seems to play a part here, as woodlands featuring a dense understorey (both coniferous and deciduous) ranked much lower than those which appeared more navigable.

Many of the woodland vegetation classes studied received higher ratings in winter than summer conditions, with the opposite being found for the more open field and grassland scenes. Thus, it seems that forests may be especially valuable as a restorative environment over other types of natural landscape during winter, presumably due to the fact they offer shelter from the elements, allow greater visual access and are easier to traverse in winter when herbaceous understorey vegetation has died back. Visibility and ease of movement also influence feelings of security in urban woodlands (Ward Thompson *et al*., 2008). Perceiving an environment as threatening negates the potential for restoration – it creates anxiety itself. Therefore any characteristics which enhance users' feelings of security should enhance the restorative potential of woodlands.

## The role of trees in the built environment

This section moves the discussion on to the value of street trees and trees as part of the landscape of built environments. These have featured strongly in studies assessing the restorativeness of built environments, and the potential cumulative benefits of retaining and incorporating nature into urban landscapes. Again, however, such studies have usually focused on natural features in general, rather than trees in particular. Regarding the specific role of trees, many studies on environmental preferences show that adding a small number of mature trees to a built scene can vastly enhance viewers' perceptions. In terms of restorative potential, the proportion of a scene formed by trees has been seen to be a predictor of ratings of the perceived restorativeness of pocket parks (Nordh *et al*., 2009).

A high profile series of studies by Frances Kuo and colleagues in the USA has investigated the cumulative effects of residents' access to green areas in a large public housing project. These studies have shown that those who lived in buildings with small greenspaces adjacent (typically a patch of grass and/or a small number of trees) are less prone to acts of intra-family aggression and violence and cope more effectively with the stress of poverty than those who live in 'barren' buildings with no adjacent greenspace or trees (Kuo, 2001; Kuo and Sullivan, 2001). The tenants in greener buildings also displayed lower levels of mental fatigue. This enhanced attentional capacity was shown to have mediated the negative relationship between nearby nature and aggression and the positive relationship with coping ability, indicating that these are not spurious associations.

Another line of enquiry has focused on the cumulative benefits of nature in window views from inside buildings. It is thought that natural features in window views allow people opportunities for 'micro-restorative' experiences in their everyday indoor environments, which, though brief, can mount up to result in a measurable cumulative benefit (Kaplan, 1993). There are now quite a number of studies that have looked at how nature in window views affects wellbeing in a variety of built environment contexts (see Table 1).

Overall, the evidence presented in this section points to the wide-ranging potential benefits of trees in the built environment on wellbeing. The fact that causal links cannot be proved from correlations in the data is a limitation of these studies. However, when taken together we see there is a considerable amount of research supporting claims that having access to nature and views of nature in everyday urban settings has a beneficial psychological effect on city-dwellers.

# Conclusions and recommendations for future research

The evidence from the research presented in this paper suggests that urban woodlands and trees in the built environment (and nature in general in the urban context) can have a measurable effect on people's wellbeing and mental health. Having access to local greenspace has a positive effect on health and particularly on mental health and diseases related to stress. Spending time in green environments, whether combined with physical activity in green exercise or simply for passive relaxation, has positive effects on a range of physiological and psychological indicators, including blood pressure, levels of stress hormones, immune system functioning, cognitive functioning, mood and self-esteem. Even having the opportunity to view trees and nature through windows appears to carry psychological benefits. The evidence supports a view of trees and woodlands as 'nature's health service', offering a supportive environment for psychological restoration from stress and mental fatigue and in the longer term buffering the negative effects of daily stresses, boosting coping capacity, and influencing positive behaviour changes and self-confidence. A consistent theme which emerges from the research is that the people that benefit the most from access to high quality greenspace are the most vulnerable – those with poor mental health status, and those living in the most deprived neighbourhoods. Public greenspaces including urban woodlands are free to all and

Table 1 Effects of nature in window views on psychological resources.

| Study | Findings | Sample |
|---|---|---|
| **Healthcare context** | | |
| Ulrich (1984) | Hospital records of patients recovering from surgery whose window view contained either trees or a brick wall were compared. Those with a view of trees required fewer doses of strong pain relief medication, were discharged earlier, and received fewer negative comments from nurses. | n=46 patients, Pennsylvania, USA |
| **Residential context** | | |
| Kaplan (2001) | Nature in window views from home was associated with higher satisfaction with the neighbourhood as a whole, and with higher self-reported ratings of wellbeing. Trees in window views predicted feelings of being at peace and a lack of trees was associated with feelings of being distracted and unable to concentrate. | n=188 residents of apartment blocks, Michigan, USA |
| Wells (2000) | Children who relocated from a home with little nature in window views to a home with more nature in view improved in their ability to concentrate. Changes in housing quality did not explain the improvements. | n=17 children, USA |
| Taylor, *et al.*, (2002) | Girls who had more nature in the window views from home displayed greater evidence of self-discipline. The same relationship was not found for boys. | n=169 children/parent pairs, Chicago, USA |
| Tennessen and Cimprich (1995) | Students with more nature in their window view performed better on attention tests. No difference was found for mood states. | n=72 undergraduate students, USA |
| **School context** | | |
| Matsuoka (2010) | Greater quantities of trees and shrubs in window views from school buildings were associated with higher test scores, graduation rates, and students' intentions to progress to higher education, and with lower levels of criminal behaviour. Large featureless expanses (e.g. lawns, sports pitches, car parking) had a negative effect. Socioeconomic and ethnic makeup of the student body, number of students and age of buildings were controlled for. | n=101 public schools, Michigan USA |
| **Workplace context** | | |
| Kaplan (1993) Study 1 | Desk workers with nature in their view reported fewer ailments in the past 6 months, and also higher job satisfaction than those without nature in view. | n=120 office workers, USA |
| Kaplan (1993) Study 2 | Desk workers' satisfaction with their window view increased with the number of natural features in view. In turn satisfaction with the view predicted perceptions of job satisfaction, task enthusiasm, patience, frustration, life satisfaction and general health. | n=615 office workers, USA |
| Leather *et al.* (1998) | A view of natural elements in window views from the workplace was found to buffer the negative effect of work stress on intention to quit, was associated with higher job satisfaction and had a marginal positive effect on general wellbeing. | n=100 wine production workers, southern Europe |

constitute an important community resource. However, the benefits of this resource for the urban population depend not just on quantity and accessibility of greenspace but also the quality of the environment.

There is still much work to be done in furthering our understanding of the value of forest, woodlands and trees in general in creating restorative environments, and of the extent of benefits of their presence on the wellbeing of the urban population. Most of the research into restorative environments has not differentiated between the effects of trees and woodland and of urban nature in general. Further focus on the specific benefits of spending time in woodland environments and of the benefits of trees in the built environment is warranted. There is also little evidence on what types of woodland and forms of management are most supportive of restoration processes, and how seasonal changes in the environment may affect these processes. Further studies assessing the perceived restorativeness of different types of urban greenspace using psychometric scales may provide a valuable line of inquiry in this respect, moving the discourse on to how we can plan, design and manage greenspace and the built environment to maximise opportunities for psychological restoration.

Another issue which deserves greater focus is individual differences in the restorative effects of nature. For the most part the literature treats restorative responses to natural environments as being innate, evolved responses which are therefore universal, although modified by cultural beliefs, life history and individual tastes. However, the focus on reporting mean values of effects on physiology, cognitive functioning, moods and behaviour may mask important patterns. The important question – 'does everyone have the potential to benefit from contact with nature?' – has received little attention. It may benefit future research on this subject to bear in mind the words of William Blake: 'The tree which moves some to tears of joy is in the Eyes of others only a Green thing that stands in the way' (Blake, 1799). It may be that there are important things to be learned not just from those who seem to benefit the most from nature experiences, but also from those who are the least affected. This may in the future help us to understand how much of the restorative effect of nature is down to evolved responses and how much is influenced by culture and social-constructions of nature (and therefore subject to change). From a pragmatic perspective, however, this could be argued to be of limited practical relevance. What we do know is that overall urban woodlands and trees provide a valuable resource for the health and wellbeing of urban residents, and they have been demonstrated to have a significant influence on population health as a whole, with particularly beneficial effects for the growing number of people experiencing high levels of stress and poor mental health.

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## References

BARTON, J. AND PRETTY, J. (2010). What is the best dose of nature and green exercise for improving mental health? A multistudy analysis. *Environmental Science and Technology* **44**, 3947–3955.

BERTO, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology* **25**, 249–259.

BLAKE, W. (1799). *Letter to Reverend Dr Trusler, 23 August 1799*. [Online] Available at: University of Georgia. http://www.english.uga.edu/nhilton/Blake/blaketxt1/Letters/5.htm [Accessed 04/03/11].

CHANG, C., HAMMITT, W.E., CHEN, P., MACHNIK, L. AND SU, W. (2008). Psychophysiological responses and restorative values of natural environments in Taiwan. *Landscape and Urban Planning* **85**, 79–84.

GRAHN, P. AND STIGSDOTTER, U.A. (2003). Landscape planning and stress. *Urban Forestry and Urban Greening* **2**, 1–18.

HAN, K.-T. (2007). Responses to six major terrestrial biomes in terms of scenic beauty, preference, and restorativeness. *Environment and Behavior* **39**(4), 529–556.

HANSMANN, R. HUG, S. AND SEELAND, K. (2007). Restoration and stress relief through physical activities in forests and parks. *Urban Forestry and Urban Greening* **6**, 213–225.

HARTIG, T. (2007). Three steps to understanding restorative environments as health resources. *In:* C. Ward Thompson and P. Travlou (eds.) *Open Space: People Space*. Taylor & Francis, Abingdon, pp. 163–180.

HARTIG, T., EVANS, G.W., JAMNER, L.D., DAVIS, D.S. AND GÄRLING, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology* **23**, 109–123.

HARTIG, T., KORPELA, K., EVANS, G.W. AND GÄRLING, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing and Planning Research* **14**, 175–194.

KAPLAN, R. (1993). The role of nature in the context of the workplace. *Landscape and Urban Planning* **26**, 193–201.
KAPLAN, R. (2001). The nature of the view from home – psychological benefits. *Environment and Behavior* **33**, 507–542.
KAPLAN, S. (1995). The restorative benefits of nature: toward an integrative framework. *Journal of Environmental Psychology* **15**, 169–182.
KORPELA, K.M., YLEN, M., TYRVAINEN, L. AND SILVENNOINEN, H. (2008). Determinants of restorative experiences in everyday favourite places. *Health & Place* **14**, 636–652.
KUO, F.E. (2001). Coping with poverty: impact of environment and attention in the inner city. *Environment and Behavior* **33**, 5–34.
KUO, F.E. AND SULLIVAN, W.C. (2001). Aggression and violence in the inner city: effects of environment via mental fatigue. *Environment and Behavior* **33**, 543–571.
LEATHER, P., PYRGAS, M., BEALE, D. AND LAWRENCE, C. (1998). Windows in the workplace: sunlight, view, and occupational stress. *Environment and Behavior* **30**(6), 739–762.
LI, Q. (2010). Effect of forest bathing trips on human immune function. *Environmental Health and Preventative Medicine* **15**, 9–17.
MAAS, J., VERHEIJ, R.A., GROENEWEGEN, P.P., DE VRIES, S. AND SPREEUWENBERG, P. (2006). Green space, urbanity, and health: how strong is the relation? *Journal of Epidemiology and Community Health* **60**, 587–592.
MAAS, J., VERHEIJ, R.A., SPREEUWENBERG, P. AND GROENEWEGEN, P.P. (2008). Physical activity as a possible mechanism behind the relationship between green space and health: A multilevel analysis. *BMC Public Health* **8**, 206–218.
MAAS, J., VERHEIJ, R.A., DE VRIES, S., SCHELLEVIS, F.G. AND SPREEUWENBERG, P. (2009).Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health* **63**, 967–973.
MATSUOKA, R.H. (2010). Student performance and high school landscapes: examining the links. *Landscape and Urban Planning* **97**, 273–282.
MITCHELL, R. AND POPHAM, F. (2007). Greenspace, urbanity and health: relationships in England. *Journal of Epidemiology and Community Health* **61**, 681–683.
MITCHELL, R. AND POPHAM, F. (2008). Effect of exposure to natural environment on health inequalities. *Lancet* **372**, 1655–1660.
MORITA, E., FUKUDA, S., NAGANO, J., HAMAJIMA, N., YAMAMOTO, H., IWAI, Y., NAKASHIMA, T., OHIRA, H. AND SHIRAKAWA, T. (2007). Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. *Public Health* **121**, 54–63.
NORDH, H., HARTIG, T., HAGERHALL, C.M. AND FRY, G. (2009). Components of small urban parks that predict the possibility for restoration. *Urban Forestry and Urban Greening* **8**, 225–235.
O'BRIEN, L. (2005). *Trees and woodlands: Nature's health service*. Forest Research, Farnham.
OTTOSSON, J. AND GRAHN, P. (2008). The role of natural settings in crisis rehabilitation: How does the level of crisis influence the response to experiences of nature with regard to measures of rehabilitation? *Landscape Research* **33**, 51–70.
PARK, B.J., TSUNETSUGU, Y., KASETANI, T., KAGAWA, T. AND MIYAZAKI, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventative Medicine* **15**, 18–26.
PERON, E., BERTO, R. AND PURCELL, T. (2002). Restorativeness, preference and the perceived naturalness of places. *Medio Ambiente y Comportamiento Humano* **3**(1), 19–34.
PRETTY, J., PEACOCK, J., SELLENS, M. AND GRIFFIN, M. (2005). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research* **15**, 319–337.
ROE, J. AND ASPINALL, P. (2011). The restorative benefits of walking in urban and rural settings in adults with good and poor mental health. *Health and Place* **17**, 103–113.
SUGIYAMA, T., LESLIE, E., GILES-CORTI, B. AND OWEN, N. (2008). Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology and Community Health* **62**(5), e9.
TAYLOR, A.F., KUO, F.E. AND SULLIVAN, W.C. (2002). Views to nature and self-discipline: evidence from inner city children. *Journal of Environmental Psychology* **22**, 49–63.
TENNESSEN, C.M. AND CIMPRICH, B. (1995). Views to nature: effects on attention. *Journal of Environmental Psychology* **15**, 77–85.
TSUNETSUGU, Y., PARK, B.J. AND MIYAZAKI, Y. (2010). Trends in research related to 'Shinrin-yoku' (taking in the forest atmosphere or forest bathing) in Japan. *Environmental Health and Preventive Medicine* **15**, 27–37.
ULRICH, R.S. (1984). View through a window may influence recovery from surgery. *Science* **224**, 420–421.
ULRICH, R.S. (1993). Biophilia, biophobia, and natural landscapes. *In:* S. R. Kellert and E. O. Wilson (eds.) *The Biophilia Hypothesis.* Island Press, Washington D.C., pp. 73–137.
VASSILJEV, P., KULDKEPP, K., KÜLVIK, M., KULL, A. AND MANDER, Ü. (2007). Recreational trail planning in the

context of seasonality. *Ecosystems and Sustainable Development* **106**, 353–364.
WARD THOMPSON, C., ROE, J. AND ALVES, S. (2008). *Woods In and Around Towns (WIAT) Evaluation, baseline survey Phase 1B report*. OPENspace, Edinburgh.
WELLS, N.M. (2000). At home with nature: effects of 'greenness' on children's cognitive functioning. *Environment and Behavior* **32**(6), 775–795.
WILSON, N.W., ROSS, M.K., LAFFERTY, K. AND JONES, R. (2008). A review of ecotherapy as an adjunct form of treatment for those who use mental health services. *Journal of Public Mental Health* **7**(3), 23–35.

# Flourishing trees, flourishing minds: nearby trees may improve mental wellbeing among housing association tenants


## Abstract

Interventions to create even a small change in the average level of mental wellbeing across the population could have very high economic and social returns. Decision makers would thus be more likely to allocate space and funding for urban trees if a positive relationship to the mental wellbeing of the surrounding population can be evidenced.

This study undertook a 'natural experiment'. It used a validated scale to quantifiably assess the effects of residential trees on mental wellbeing, within largely randomly assigned participants living in housing association properties, with the significant environmental and socio-economic variables held broadly constant. It used a bespoke scale, set against statements, to quantifiably assess participants' general perceptions of residential trees and this relationship on mental wellbeing.

Tenants with high nearby tree cover had a higher mean reported mental wellbeing than those with negligible levels, indicating that nearby trees may provide aids in improving mental wellbeing for certain groups. There was a generally positive response to nearby trees and a desire from those with negligible existing levels for increased tree cover. While avoiding sweeping claims, the implications are that investments in residential trees could result in higher mean levels of mental wellbeing for certain groups, with the associated benefits this brings to the individual and wider community.


## Introduction

The common assumption that contact with nature fosters mental wellbeing and reduces the stress of urban living is seemingly as old as urbanisation itself (Ulrich *et al*., 1993). The first great act of greenspace creation in modern history, the Victorian park, occurred because the park-makers believed intuitively in the healing and redemptive values of nature (Nicholson-Lord, 2006).

Greater pressure on urban land is now limiting the space available for trees (Britt and Johnston, 2008); thus intuitive arguments for increased tree cover carry little weight with decision makers who have to justify all outgoing costs. The resources allocated to urban forestry programmes are heavily influenced by the extent to which rigorous research demonstrates that such measures improve outcomes and are cost effective.

It is now accepted that interventions to create even a small change in the average level of mental wellbeing across the population could have very high economic and social returns (Jenkins *et al*., 2008); thus decision makers will be more likely to allocate space and funding for urban trees if a positive relationship to the mental wellbeing of the surrounding population can be evidenced.

This research aimed to objectively assess the potential of nearby trees to improve the mental wellbeing of residents living in poorer urban communities, and to understand the intrinsically linked issues of how these residents perceive trees and negotiate this relationship with mental wellbeing.


**Keywords:**

attitudes, mental health, residential trees, urban forestry



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## Mental wellbeing

Despite a large amount of related research, it is suggested that a single definition of mental wellbeing remains unresolved (Carlisle and Hanlon, 2008). However, it is agreed that the term encompasses more than the absence of mental illness; mental wellbeing being something we all have and seek to improve. The term is often used interchangeably with the terms positive mental health or psychological wellbeing or simply wellbeing. The World Health Organisation (2004) defined positive mental health as a state which allows individuals to realise their abilities, cope with the normal stresses of life, work productively and fruitfully, and make a contribution to their community.

Mental wellbeing is described as a continuum ranging from good or high mental health, or flourishing, at one end, to poor mental health, or languishing, at the other end of the continuum (Keyes, 2002). Historically, mental health measurement has divided the population into those who meet the criteria for diagnosis of mental illness and those who do not. However, such methods are unable to distinguish average from good mental health (Stewart-Brown *et al*., 2009).

Recent developments confirm mental wellbeing as a valid construct that can be measured reliably. The Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS) (Parkinson, 2006) is now an established approach to the assessment of mental wellbeing at population levels; it was developed specifically to measure positive mental health with all the items representing positive thoughts or feelings. It has been used in several large-scale health surveys and is to be included in the National Health Survey for England in 2011 (Deacon *et al*., 2009).

Factors found to affect mental wellbeing include an individual's genotype (Argyle, 1999; Keverne, 2005), socially developed characteristics (McKee-Ryan *et al*., 2005) and socio-economic factors; whereby the higher people are on the social hierarchy the lower their risk of poor mental health (Bajekal and Osbourne, 2006). It is also accepted that the built environment may potentially affect wellbeing through multiple pathways (Northridge *et al*., 2003).

The cost of mental ill health and poor mental wellbeing to the care and wider economy is estimated at £76 billion per annum (SDC, 2008). As such, if interventions were to create even a small change in the average level of mental wellbeing across the population they could have very high economic and social returns (Jenkins *et al*., 2008). Because of this, mental wellbeing research is producing a burgeoning evidence base for policy, aiming to promote positive mental wellbeing as a target for population-level interventions (Marmot Review, 2010).

## Can the urban forest promote mental wellbeing?

Urban trees mitigate many negative environmental impacts such as the heat island effect, flooding and air pollution, thus having many indirect health and wellbeing benefits. However, the mechanisms by which urban trees or 'nature' may independently provide specific health and mental wellbeing benefits have been largely underpinned by psycho-evolutionary or 'biophilia' theory, whereby millions of years of evolution have left modern humans with a partly genetic predisposition to respond positively to nature (Wilson, 1984; Kellert, 1993).

In applied research the two prominent restorative theories, separate yet congruous with the biophilia hypothesis, attempt to evidence how such affects on health take place. Psycho-physiological stress recovery theory (Ulrich *et al*., 1991) suggests that health effects occur because experiencing and viewing natural scenes immediately initiates the physiological and psychological responses that underpin recovery from stress. Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989) suggests natural environments allow the human brain, fatigued from the prolonged directed attention required in urban areas, to be refreshed.

Generally underpinned by one of these two theories, an increasing amount of research has attempted to test links between greenspace, health and wellbeing. Recent general reviews of the evidence include Maller *et al*., (2008), O'Brien *et al*., (2010) and Lee and Maheswaran, (2011). The research can be broadly grouped into descriptive studies, including epidemiological and qualitative studies, and quasi-experimental studies. While proving causality is difficult, the quantity and variety of research suggests that greenspace can improve mental wellbeing and that it can be of particular benefit to people from more deprived urban communities. However, Lee and Maheswaran's (2011) review highlights a lack of robust evidence, noting many studies were limited by poor study design.

A methodological weakness with much of the existing research is confounding. While able to factor for direct selection effects such as income, most studies are unable to distinguish personal characteristics and cannot therefore differentiate whether green environments lead to increases in health and wellbeing or whether healthier and happier people self-select into greener neighbourhoods. Many are small studies with poor statistical power, relying heavily on anecdotal evidence. There is often also the possibility of information bias, based on the subject's preconceptions and them wanting to please investigators with their responses. Most studies do not distinguish between different types of greenspace and fail to identify the specific role of urban trees as a constituent part, or else compare even more loosely defined 'urban' and 'natural' environments. Thus robust generalisations in relation to tree cover in an urban residential context are difficult. Similarly, there are complexities around the perceptions of trees, with access and social inequality issues inextricably linked to any possible benefits gained.

Largely as a result of the complications involved in randomly assigning people to specific settings, there are few robust randomised controlled trials. However, some studies have undertaken 'natural experiments', which overcame many of the aforementioned design weaknesses. These include those that used randomly assigned tenants of public housing (Kuo, 2001; Kuo and Sullivan, 2001a, 2001b); or surgery patients who had a bedside window view of either trees or a brick building wall (Ulrich, 1984). These early quasi-experimental studies provide some of the most robust evidence that exposure to views of trees may have restorative effects in terms of cognitive function and stress reduction. Their relative methodological strength is highlighted by their continued reference in even the most recent recommendations and policy (e.g. Marmot Review, 2010; British Medical Association, 2011).

Explicit research gaps identified in the reviews include the importance of trees very close to residences to mental wellbeing; clarification of the relative importance of trees as a potential mental health mechanism in deprived urban communities; and research to explore residents' understandings of the relationship between trees and health and wellbeing. This study aimed to address these research issues by asking the following questions.

## Research questions

- With all other significant variables held broadly constant, do randomly assigned tenants living in properties with high levels of nearby tree cover have a higher reported mental wellbeing than those with negligible levels?
- What are tenants' general attitudes towards nearby trees and how does this relate to mental wellbeing?

# Method

## The basic approach

Aiming to adhere to the spirit of Kuo's (2001) methodological criteria, this study undertook a 'natural experiment'. It used a validated mental wellbeing scale to quantifiably assess the effects of residential trees within largely randomly assigned participants living in housing association properties, with the significant environmental and socio-economic variables held broadly constant. It used a bespoke scale, set against statements, to quantifiably assess participants' general perceptions of residential trees and this relationship to mental wellbeing.

## Sample group

The sample group were tenants renting properties from Chevin Housing Association (CHA), a charity that owns and manages around 6000 rented homes, predominantly throughout the Yorkshire region. Properties are focused on those in the lower-income brackets or in particular need. CHA lettings policy defines people in the most need via a banding system depending upon applicants' circumstances. Because rent is subsidised, most properties have a waiting list and, although applicants can apply for their choice of scheme, in practical terms, limited availability means that when a flat becomes available it is taken by those next on the waiting list. This results in a largely random assignment of residents and provides the advantages of a near-randomised trial, with selection bias (of the people choosing flats with nearby trees differing from people who choose flats without trees) largely removed. Tenants have no direct role in managing the trees outside their buildings, including decisions to introduce or remove trees.

## Variables

Socio-demographic variables shown to have significant differences on mental wellbeing were ascertained through details held by CHA and from the Office for National Statistics. The two participant groups were thus broadly homogeneous with regard to age, gender, tenants in single living accommodation, tenants identifying themselves as black or ethnic minorities, and those identifying themselves as having a disability. Any minor variations were assessed via a t-test and were not statistically significant.

The Index of Multiple Deprivation provides a nationally consistent measure of how deprived an area is by identifying the degree to which people are disadvantaged by factors such as low income, unemployment, lack of education, poor health and crime at Lower-layer Super Output Area (LSOA) level in England. The four neighbouring local authorities used within this study rank 5th, 6th, 7th, and 8th from the list of 21 within the Yorkshire region. All have a similarly high relative proportion of LSOAs in the most deprived quintile (ONS, 2007).

No specific participant income data was assessed as part of this study. However, due to the CHA lettings policy it is reasonable to assume an even mix of income types and employed/unemployed tenants exists within the two groups. Within the wider social rented sector, over half the households are economically inactive and unemployment is higher than any other household type (ONS, 2009).

Objective quantified measures were used as the basis for assignment to conditions of high surrounding tree cover ('green') (see Figure 1) or negligible surrounding tree cover ('grey') (see Figure 2). Data from the Office for National Statistics ensured there were no systematic differences between grey and green schemes in levels of surrounding greenspace within the wider ward area and in amount of land that was occupied by buildings and roads. A measurement of the nearest open greenspace from each selected scheme was obtained from Google Earth imagery, ensuring all schemes had some greenspace within 300 metres, as per the Standard from Natural England (2009). Other environmental variables were assessed using data held by CHA, Google Earth imagery and site visits, ensuring size, layout and number of residential units were broadly constant throughout the two groups.

Significant grassed areas and shrub beds were limited throughout all the schemes, thus vegetation was largely limited to tree cover. However, in practical terms it was not possible to have grey scheme views completely barren; several had some limited vegetation within the surrounding landscape. Furthermore, while the wider environment was assessed, it cannot be assumed that there were no occasional trees on the horizon, visible from the upper floors.

Evidently participants were not 'blind' to their surroundings, but were 'blind' as to the ultimate specifics of the research, with the mental wellbeing scale being undertaken first prior to any specific mention of trees, so as to avoid any information bias or confounding responses.

## Measures

The independent variable of the study was nearby trees; the primary dependent variable was mental wellbeing. This was measured with the Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS). It uses a five-point scoring system, with responses ranging from 'none of the time' through to 'all of the time'. A score is attributed to each response for each of the seven items in the scale:

- I've been feeling optimistic about the future
- I've been feeling useful
- I've been feeling relaxed
- I've been dealing with problems well
- I've been thinking clearly
- I've been feeling close to other people
- I've been able to make up my own mind about things

*Scores:*
None of the time = 1. Rarely = 2. Some of the time = 3. Often = 4. All of the time = 5.

**Figure 1** High tree cover 'green scheme'.

**Figure 2** Negligible tree cover 'grey scheme'.

The secondary dependent variable for the study was attitudes to residential trees, and the belief in the power of trees and the environment to be salubrious. This was measured with a similar Likert scale, asking residents to agree/disagree to a series of opinion statements on a five-point scale, with possible responses ranging from one (strongly disagree) to five (strongly agree):

- It's important to me how the local area looks
- I would like to see more trees around where I live
- How the local environment looks makes a difference to how I feel
- Trees should be in parks and woodlands, not close to where I live
- Trees and nature make me feel calm and relaxed
- Trees around flats cause too many problems

Both scales use a five-point system, thus individuals were given a mean score for each scale and for each statement. T-tests allowed for the mean ratings for the green and grey group to be compared. To account for any invalid responses if a response to one item was missing, a midpoint score of three was used. Across the two groups, four respondents (2% of participants) did not have a full total score.

## Procedure

Following CHA consent, variables were assessed resulting in 14 comparable schemes (7 grey and 7 green) with 425 potential properties (196 grey and 229 green). An introductory letter to tenants was composed, with advice from members of CHA with relevant expertise. This clearly outlined what would be involved in the research and requested those who did not wish any further part to opt out before the date specified. Any tenants deemed unsuitable by CHA due to ethical or safety reasons were removed from the mailing list and the letter was posted to 388 tenants. The schemes were then visited between 10am and 6pm over a three-week period in October 2009. Individual potential participants were contacted via residential intercoms. After an initial introduction, consenting participants then came to their doorstep and were invited to self-complete the SWEMWBS followed by the attitudinal scale.

# Results

## Participant response

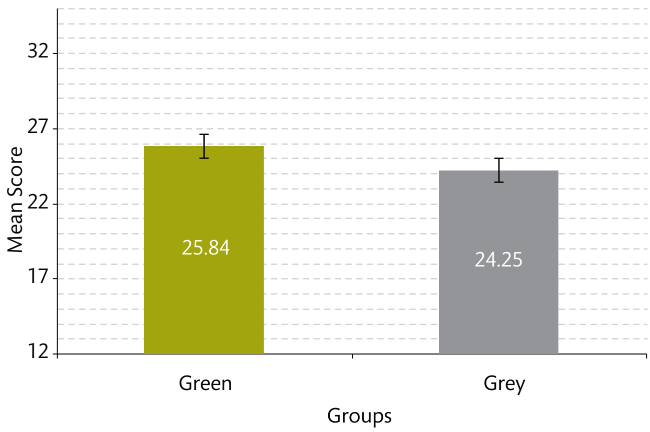
Of the 388 tenants who were invited to participate, 63 tenants chose to opt out of any further participation; yielding a final sample of 325 (170 green and 155 grey). Of the properties visited, two participants refused, when asked for further consent, after looking at the SWEMWBS scale. Approximately 15% of participants were unable or unwilling to self-complete the scales, thus the researcher read out the statements and completed the scales as per their response. Data collection stopped after 200 responses (100 green and 100 grey) had been collected. All of the schemes were visited, with several schemes requiring multiple visits so as to find the tenants at home.

# Discussion

## Answering the main research question

The difference between the grey and green group participants combined mean is considered to be statistically significant ($t = 2.2622$, $df = 198$, $p < 0.0248$). Thus the study has shown that there is a statistically significant difference in the mean reported mental wellbeing of randomly assigned tenants; those with high nearby tree cover had a higher mean reported mental wellbeing than those with negligible levels (Figure 3).

**Figure 3** Group mental wellbeing means.




The mean mental wellbeing score for all participants was 25.04. The standard deviation was 4.97. Thus cut-off points were applied, based on one standard deviation above or below the mean. This allowed comparisons of mental wellbeing levels as assessed by the proportions of populations with relatively high, moderate and low mental wellbeing. Interestingly, a significantly higher proportion of the green group participants had a high (flourishing) level of mental wellbeing, yet the grey group did not have a larger proportion with lower than average (languishing) wellbeing (Figure 4).

Of the seven SWEMWBS statements, there were no significant differences of combined mean scores by group for 'feeling optimistic' (t = 0.1335, df = 198, p <0.8940), 'dealing with problems well' (t = 1.7012, df = 198, p <0.0905), 'feeling close to others' (t = 1.3676, df = 198, p <0.139) and 'able to make my own mind up', with both groups having a mean score of 4.1.

There were very significant differences between the two groups' mean scores for the statements 'feeling useful' (t = 2.8806, df = 198, p <0.0044) and 'feeling relaxed' (t = 3.0224, df = 198, p <0.0028), and there was a significant difference for 'thinking clearly' (t = 2.5347, df = 198, p <0.0120), with the green group scoring a higher mean score for these statements (Figure 5).

Figure 4 Distribution of wellbeing scores between groups.

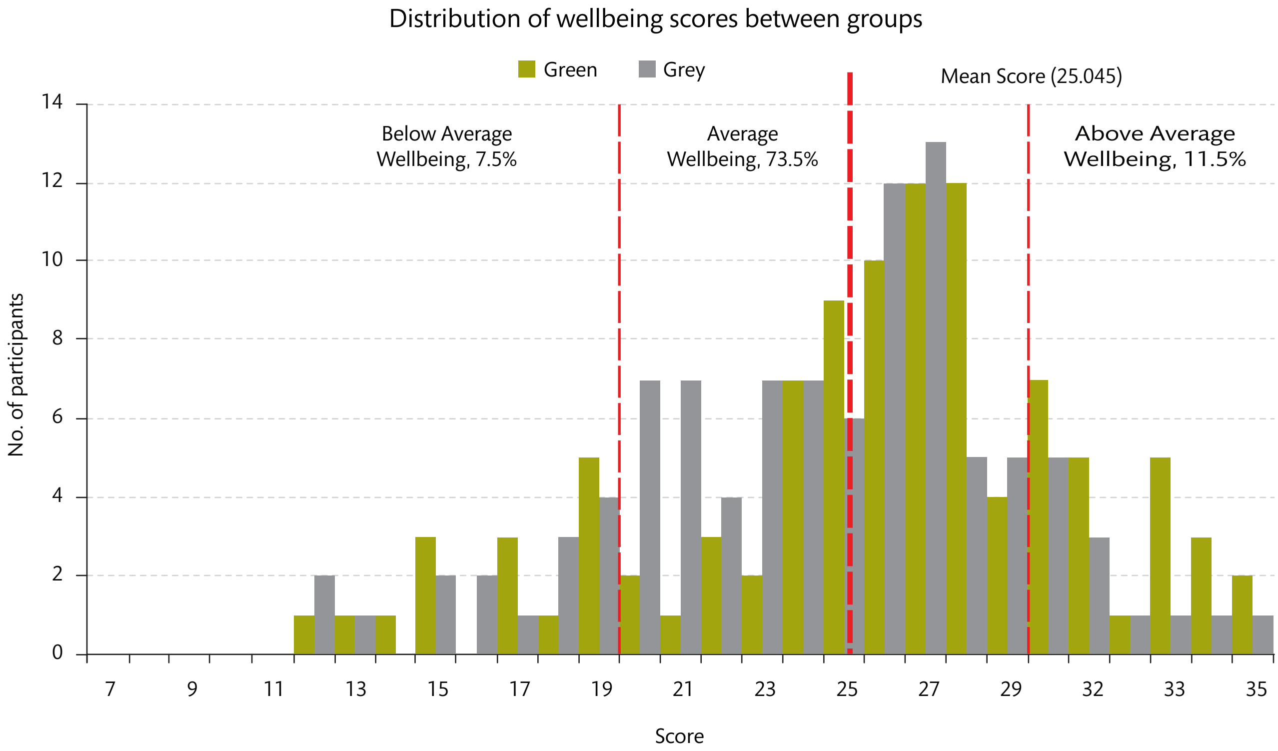



Figure 5 Mean results of SWEMWBS statements.

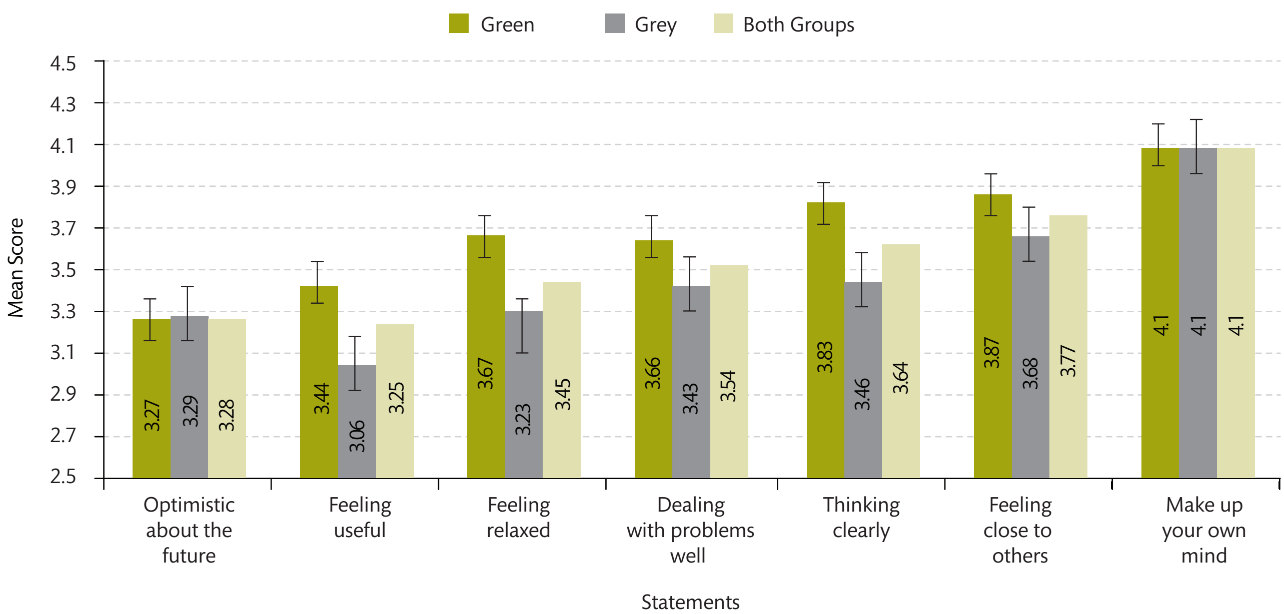
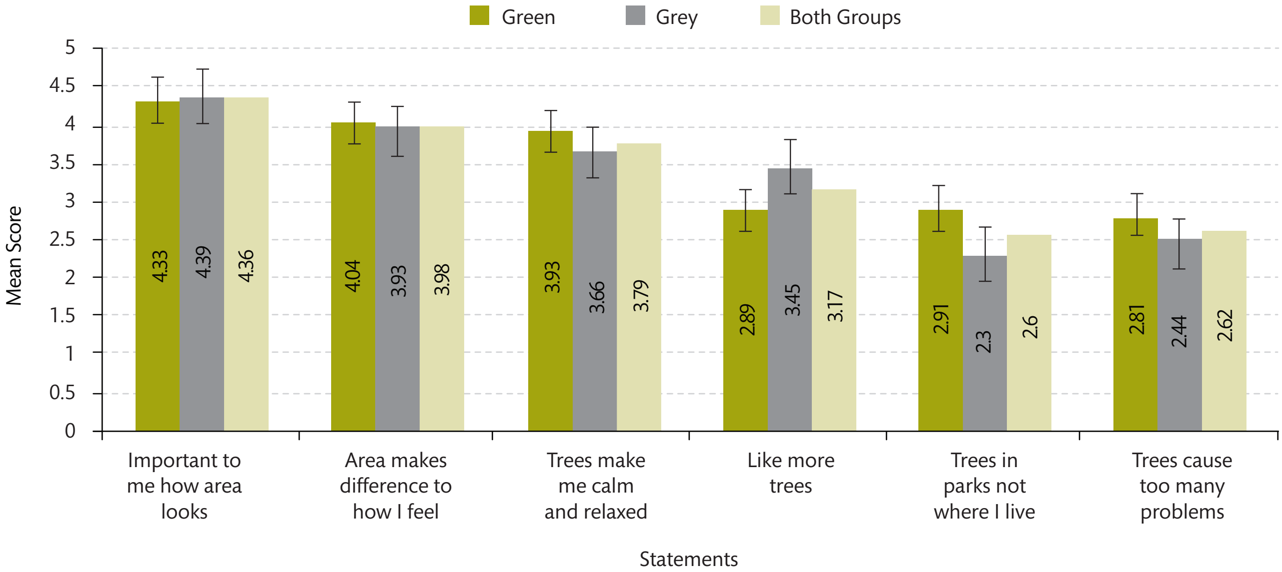


**Figure 6** Participant attitudinal statement results.




## Relating these results to existing knowledge

The most striking difference between the two group means was for the statement 'I've been feeling relaxed'. While no specific physiological measure of stress was undertaken, it is not unreasonable to suggest feeling relaxed is the antonym of feeling stressed. Thus this result is broadly consistent to Ulrich *et al*.'s (1991) theory and research of stress reduction, whereby the mechanism responsible for health effects occur because experiencing and viewing natural scenes immediately initiates the physiological and psychological responses that underpin recovery from stress.

Similarly, although the study did not use specific tests of directed attention, both the 'thinking clearly' and 'feeling useful' statements could be understood as aspects of restored capabilities of cognitive function. Thus these findings are broadly congruent with ART theory (Kaplan and Kaplan, 1989) and its wider body of research on cognitive function and greenspace (e.g. Kuo and Sullivan, 2001a).

Other than more general research relating to the wider impact of the surrounding environment on mental wellbeing (Northridge *et al*., 2003), there is no explicit evidence from the existing literature as to why the statements relating to optimism, dealing with problems and making up one's own mind would have a specific association with surrounding tree cover. It is conceivable that higher levels of social interaction resulting from nearby trees would have been evidenced by a higher green group mean score for the statement 'I've been feeling close to others', yet there were no significant differences of combined mean scores by group for this statement. This apparent lack of significance may be a limitation of the understood meaning of the scale statement or method of measurement, or it may be suggestive of no significance in relation to social interaction and nearby trees.

## Attitudinal survey

A secondary aim of the study was to assess attitudes to nearby trees within largely randomly assigned tenant populations. The results show that attitudes towards nearby trees are generally positive. There was general disagreement or neutrality to the statements 'Trees should be in parks and woods, not close to where I live' and 'Trees around flats cause too many problems'. However, these statements did receive some noticeable support, with almost a quarter of all respondents 'agreed' or 'strongly agreed' with the respective statements. Yet overall those who did not wish to see more trees were in the minority (26.5%), which is a relatively small number considering the high levels of tree cover at the green sites (Figure 6).

## Attitudes by group

There is a very statistically significant difference by group for the statements 'I would like to see more trees around where I live' ($t = 3.8584$, $df = 198$, $p < 0.0002$), with the grey group scoring a higher score, and for 'Trees should be in parks and woods, not close to where I live' ($t = 4.2790$, $df = 198$, $p < 0.0001$), with the green group scoring a higher mean score. There is a smaller but still significant difference for 'Trees and nature make me feel calm and relaxed' ($t = 2.2956$, $df = 198$, $p < 0.0227$) and 'Trees around flats cause too many problems' ($t = 2.0709$, $df = 198$, $p < 0.0397$), with the green group scoring a higher mean score for these statements.

Grey group participants generally had a desire to have more trees around where they live; only 14% had a negative response to the statement 'I would like to see more trees around where I live'. Conversely, 39% of the green group had a negative response to this statement. However, as the green sites were specifically selected due the high levels of surrounding tree cover, this may not be evidencing an adverse response to the existing levels of tree cover, but simply be acknowledging that the current levels are adequate.

There is a clear trend throughout the groups for the statements 'Trees should be in parks and woods, not close to where I live' and 'Trees around flats cause too many problems', with around twice as many of the grey group disagreeing, while the green group were more likely to neither agree nor disagree or agree with the statements. This is understandable, as those tenants living in schemes with high tree cover will clearly have a more direct understanding of any associated problems that come from living in close proximity to trees.

## The impact of beliefs

There was a strong belief from the participants in both the power of the surrounding environment and trees and nature to have beneficial effects on mental wellbeing. Only 6.5% of all participants disagreed or strongly disagreed with the statement 'Trees and nature make me calm and relaxed', and the green group participants were more likely to agree or strongly agree with the statement. This suggests that an appreciation of trees in this regard is enhanced with direct experience and highlights such dispositions, although conceptually understood and agreed with, may not fully actualise without direct experience.

Such an overwhelming lack of disagreement in the ability of trees and nature to relax people leads to perhaps the simplest explanation for the study's key findings, based on the power of people's believe systems or 'meaning effect'. Although the term may have negative connotations, the power of 'placebo' is widely documented and accepted in the medical field. Thus, while it is tempting to infer a psycho-evolutionary response or 'biophilia' as an explanation for the study's key results it would be rash to do so, as it is possible that the mechanisms by which mental wellbeing benefits take place are derived from people's belief systems. Such a mechanism would not undermine the restorative value of trees, but highlights the importance of the cultural meaning placed upon them.

## Strengths, weaknesses and further research

The results of the study are supportive of much previous research on greenspace and wellbeing links. However, the study was unique in a number of ways.

The surrounding levels of nearby greenspace were broadly similar between the two groups, thus the study specifically assessed nearby residential trees as opposed to 'greenspace'. However, no assessment of the quality of the greenspace was undertaken, nor was it assessed whether the participants used or were aware of it.

The vast majority of previous related work looks at how greenspace can reduce stressed or mentally fatigued individuals. This research did not look at how nearby trees may alleviate negative mental states but how they encourage positive mental states.

While all reasonable attempts were made at minimising any confounding factors, it must be accepted that in order to gain enough participant responses to make statistical analysis valid, the study essentially grouped 14 schemes in different immediate geographic locations into two groups. Thus it is always possible that unaccounted for variables other than surrounding trees may have influenced the results. Similarly, the specific characteristics of the sample group, tenants in housing association properties, cannot be extrapolated to the wider society without some caution.

The study is the first to use a nationally standardised measure of mental wellbeing to assess the impact of surrounding trees, and provides encouraging results as to the scale's wider application in future related studies. It is suggested that researchers should be alert to opportunities for similar 'natural experiments', possibly using existing or proposed urban developments or healthcare facilities, to further examine this potential of trees.

# Conclusion

The results of the study suggest that nearby residential trees may provide aids in improving mental wellbeing for more disadvantaged socio-economic groups. It has shown significant differences in mean mental wellbeing scores between randomly assigned populations who reside in similar housing schemes that largely differ only in the presence or absence of nearby trees. However, caution is advised before making claims regarding positive mental wellbeing benefits on this evidence alone, as there is a risk that this could lead to expectations about the effect of residential trees that could lead to disappointment.

The study also shows clearly that people generally respond positively to nearby trees and that there is a desire for those living in poorer urban areas with low tree cover to see more trees around where they live.

How nearby trees may be responsible for improved mental wellbeing scores is difficult to establish. The three statements with significant statistical differences could be understood conceptually in terms of stress reduction theory and ART, which is encouraging. Yet the results provide no direct evidence as to whether the mechanisms are culturally defined or biologically based. However, this should not detract from the study's key results. The implications of these are that investments in nearby residential trees could result in disadvantaged socio-economic groups having higher mean levels of mental wellbeing, with the considerable associated benefits that this has on the individual and wider community.

## References


ARGYLE, M. (1999). Causes and correlates of happiness. *In:* D. Kahneman, E. Diener and N. Schwartz (eds). (1999). *Well-being, the foundations of hedonic psychology*. Russell Sage Foundation, New York, pp. 353–373.

BAJEKAL, M. AND OSBOURNE, V. (2006). *Focus on health*. Palgrave Macmillan, Hampshire.

BRITISH MEDICAL ASSOCIATION (2011). The psychological and social needs of patients. *BMA Science & Education*, January 2011.

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II. A new survey of urban trees in England and their condition and management*. Department of Communities and Local Government, London.

CARLISLE, S. AND HANLON, P. W. (2008). Wellbeing as a focus for public health? A critique and defense. *Critical Public Health* **18**, 263–270.

DEACON, L., CARLIN, H., SPALDING, J., GILES, S., STANSFIELD, J., HUGHES, S., PERKINS, C. AND BELLIS, M.A. (2009). *North West Mental Wellbeing Survey 2009 Summary*. North West Public Health Observatory, Liverpool John Moores University.

JENKINS, R., MELTZER, H., JONES, P.B., BRUGHA, T., BEBBINGTON, P., FARRELL, M., CREPAZ-KEAY, D. AND KNAPP, M. (2008). *Foresight Mental Capital and Wellbeing Project. Mental health: Future challenges*. The Government Office for Science, London.

KAPLAN, R. AND KAPLAN, S. (1989). *The Experience of Nature. A Psychological Perspective*. Cambridge University Press.

KELLERT, S. (1993). The biological basis for human values of nature. *In:* Kellert, S.R. and Wilson, E.O. (eds.), *The Biophilia Hypothesis*. Island Press, Washington D.C., pp. 42–69.

KEVERNE, E.B. (2005). Understanding well-being in the evolutionary context of brain development. *In:* Huppert, F.A, Baylis, N. and Keverne, B. (eds). *The Science of Well-being*, pp. 35–56. Oxford University Press.

KEYES, C.L.M. (2002). The mental health continuum: From languishing to flourishing in life. *Journal of Health and Social Behavior* **43**, 207–222.

KUO, F.E. (2001). Coping with poverty: Impacts of environment and attention in the inner city. *Environment and Behavior* **33**(1), 5–34.

KUO, F.E. AND SULLIVAN, W.C. (2001A). Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and Behavior* **33**(4), 543–571.

KUO, F.E. AND SULLIVAN, W.C. (2001B). Environment and crime in the inner city. Does vegetation reduce crime? *Environment and Behavior* **33**(3), 343–367.

LEE, A.C.K. AND MAHESWARAN, R. (2011). The health benefits of urban green space: A review of the evidence. *Journal of Public Health* **33**(2), 212–222.

MALLER, C., TOWNSEND, M., ST LEGER, L., HENDERSON-WILSON, C., PRYOR, A., PROSSER, L. AND MOORE, M. (2008). *Healthy parks, healthy people: The health benefits of contact with nature in a park context. A review of relevant literature*. 2nd edition. Deakin University and Parks Victoria. Burwood, Melbourne.

MARMOT REVIEW (2010). *Fair society, healthy lives*. Strategic Review of Health Inequalities in England Post 2010. The Marmot Review, London.

MCKEE-RYAN, F., SONG, Z., WANBERG, C.R. AND KINICKI, A. J. (2005). Psychological and physical well-being during unemployment: a meta-analytic study. *Journal of Applied Psychology* **90**(1), 53–76.

NATURAL ENGLAND (2009). *Standards for accessible natural greenspace*. [Online] Available at: http://www.naturalengland.org.uk/ourwork/enjoying/places/greenspace/greenspacestandards.aspx [Accessed 05/12/09].

NICHOLSON-LORD, D. (2006). Cities for biophiliacs. *In:* Norman, J. (ed.) *Living for the City*. Policy Exchange, London.

NORTHRIDGE, M.E., ELLIOTT, S.D. AND BISWAS, P. (2003). Sorting out the connections between the built environment and health: A conceptual framework for navigating pathways and planning healthy cities. *Journal of Urban Health: Bulletin of the New York Academy of Medicine* **80**(4), 556–567.

O'BRIEN, E., WILLIAMS, K. AND STEWART, A. (2010). *Urban health and health inequalities and the role of trees, woods and forests in Britain: a review*. Report to the Forestry Commission. Forest Research.

ONS (2007). *Index of Multiple Deprivation, for local authorities in Yorkshire and The Humber Office for National Statistics*. Similarities and differences between the indices of deprivation across the UK. [Online] Available at: http://www.neighbourhood.statistics.gov.uk/dissemination/Info.do?page=aboutneighbourhood/indicesofdeprivation/indices-of-deprivation.htm [Accessed 10/04/10].

ONS (2009). *English Housing Survey 2009*. Office of National Statistics.

PARKINSON, J. (2006). *Measuring Positive Mental Health: Developing a New Scale*. [Online] Available at: www.healthscotland.com/uploads/ [Accessed 16/11/09].

SDC (2008). *Health, place and nature. How outdoor environments influence health and well-being: a knowledge base*. Sustainable Development Commission. [Online] Available at: www.sdcommission.org.uk/publications/downloads/Outdoor_environments_and_health.pdf/ [Accessed 02/04/2010].

STEWART-BROWN, S., TENNANT, A., TENNANT, R., PLATT, S., PARKINSON, J. AND WEICH, S. (2009). Internal construct validity of the Warwick-Edinburgh Mental Well-being Scale (WEMWBS): a Rasch analysis using data from Scottish Health Education Population Survey. *Health and Quality of Life Outcomes* **7**(15), 1–8.

ULRICH, R.S. (1984). View through a window may influence recovery from surgery. *Science* **224**, 420–421.

ULRICH, R.S., SIMONS, R., LOSITO, B.D., FIORITO, E., MILES, M.A. AND ZELSON, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology* **11**, 201–230.

ULRICH, R.S., LUNDÉN, O. AND ELTINGE, J.L. (1993). Effects of exposure to nature and abstract pictures on patients recovering from heart surgery. Paper presented at the Thirty-Third Meeting of the Society for Psychophysiological Research, Rottach-Egern, Germany. *Abstract in Psychophysiology* **30** (Supplement 1), 7.

WILSON, E.O. (1984). *Biophilia*. Harvard University Press, Cambridge, Massachusetts.

WORLD HEALTH ORGANISATION (2004). *Promoting Mental Health; Concepts emerging evidence and practice. Summary report*. World Health Organisation, Geneva.

# The use of trees in urban stormwater management

## Abstract

Sustainable stormwater management presents unique challenges and opportunities in the urban built environment. The disposal of stormwater directly from impervious urban surfaces into surrounding waterways is detrimental to the aquatic environment. In response to this, processes such as evapotranspiration and soil and groundwater recharge are increasingly being used so that hydrological patterns of urban areas more closely mimic natural areas. Vegetation, including urban trees, affects many of these processes and is an important component of stormwater management.

An experiment was conducted in Melbourne, Australia, to assess the potential role of street trees in urban biofiltration systems. Four tree species, *Eucalyptus polyanthemos* (red box), *Lophostemon confertus* (brush box), *Callistemon salignus* (willow bottlebrush) and *Platanus orientalis* (oriental plane) were grown in three different constructed soil profiles, including one chosen for its low, and potentially growth limiting, drainage rate. The plants were irrigated with tapwater (potable) or a model stormwater solution. In general, tree growth, in all soils, was increased when the irrigation was with the model stormwater solution.

Compared to unplanted controls, the presence of trees in the biofiltration system resulted in significant reductions of the soluble nitrogen and phosphorus concentrations of the stormwater. In general, biofiltration systems effectively reduced the filterable reactive phosphorus (FRP) concentration of stormwater. The treatment of nitrate plus nitrite ($NO_X$) concentration of stormwater was more variable from planted systems, with reductions achieved during cooler months while $NO_X$ was generated during warmer months.

Species selection did not appear to be an important element in terms of system success. Profiles planted with the deciduous species performed similarly in terms of nutrient removal to the systems with evergreen species, although there was some seasonal variation. Incorporating street tree plantings as stormwater treatment measures offers an exciting opportunity to create multi-functional landscapes.

## Introduction

**Keywords:**

trees, stormwater, biofiltration

Urbanization changes many attributes of the land that is developed. One of these is a reduction in the permeability of surfaces that can lead to modified patterns of runoff and increased loads of pollutants entering downstream waterways. The degree of impervious surfaces or perhaps more importantly the nature of the pathway between where the stormwater is generated and where it flows into the receiving waters, can be important predictors of the extent of disturbance to the health of aquatic ecosystems (Hatt *et al*., 2004; Taylor *et al*., 2004; Walsh, 2004,). Approaches that are used to offset this disturbance are known by various names that include water sensitive urban design (WSUD) (Australia), sustainable urban drainage systems (SUDS) (UK) and low impact development (LID) (USA). Urban trees are an important component of these more sustainable approaches to stormwater management.

Biofiltration systems, also known as raingardens or biofilters, are one of the strategies used as part of WSUD to improve the quality and reduce the quantity of urban stormwater runoff. Biofiltration systems direct stormwater runoff into a treatment area that has plants growing in a moderately permeable soil. The runoff percolates through the system and a combination of physical, chemical and biological processes reduces the nutrient and

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sediment load of the runoff. The volume and speed of delivery of runoff directed into waterways is also reduced if stormwater is retained within the systems. Most biofilters use herbaceous species (grasses, sedges and rushes are common) but in highly urbanized locations, such as streets, trees may be more suitable vegetation. While an extensive literature exists that discusses the performance of predominantly herbaceous biofiltration systems (Davis *et al*., 2006; Blecken *et al*., 2007; Henderson *et al*., 2007, Bratieres *et al*., 2008; Read *et al*., 2008) systems using large, woody vegetation are less well documented.

This paper examines existing literature on the performance of woody plants in stormwater management systems and reports on an experiment that investigated the use of four street tree species (*Eucalyptus polyanthemos, Lophostemon confertus, Callistemon salignus* and *Platanus orientalis*) in model infiltration systems. All of these species are used as street trees in southeastern Australia.

# The use of woody plants in stormwater management systems

Urban trees can contribute to stormwater management in a number of ways. Stormwater runoff can be reduced by the evaporation of rainfall intercepted by the canopy and transpiration losses, while stormwater quality can be improved by retention of pollutants in soil and plant uptake (Stovin *et al*., 2008).

## Rainfall interception in canopy

The volume of runoff is reduced by the evaporation of rainfall from leaf surfaces within the tree canopy. Rainfall interception by trees in the parks and streets of a Californian city equated to 1.6% of total precipitation and a saving of $3.80 per tree on expenditure for stormwater management (Xiao and McPherson, 2002). Rainfall interception is maximized with large, evergreen tree species (Xiao and McPherson, 2002).

## Increased infiltration of rainfall and soil water storage

Trees can increase the rate or amount of soil water infiltration and subsequently increase soil and groundwater recharge. A proportion of the rainfall temporarily held on the canopy will flow down the stem and trunk (Xiao *et al*., 2000). In highly impervious areas this trunk flow increases the likelihood that rainfall is directed into soil at the base of the tree rather than onto surrounding impervious surfaces.

Tree pits can be designed to maximize water storage. The use of structural soil under pavement areas such as car parks and footpaths to retain stormwater is an example of this. By providing increased rooting volumes through the use of structural soils, these systems should support larger-sized trees and will further mitigate stormwater by rainfall interception and retention within the soil (Day *et al*., 2008). *Fraxinus pennsylvanica* (green ash) and *Quercus bicolor* (swamp white oak) grew successfully in structural soil planting pits that were designed to retain stormwater (Bartens *et al*., 2009).

The percolation of stormwater through compacted soil layers can also be increased by tree root growth. The saturated hydraulic conductivity (SHC) of a compacted subsoil layer under structural soil was 0.79 mm $h^{-1}$ (27-fold higher) with *Fraxinus pennsylvanica* (green ash) than in unplanted systems (Bartens *et al*., 2008). *Acer rubrum* (red maple) and *Quercus velutina* (black oak) increased the saturated hydraulic conductivity of compacted clay soil in less than 12 weeks after planting (Bartens *et al*., 2008).

## Pollutant removal

In addition to reducing the quantity of urban runoff, vegetation and its associated soil can play an important role in removing nutrients and heavy metals from stormwater (Davis *et al*., 2001, Henderson *et al*., 2007, Read *et al*., 2008). To date there has been limited research on the performance of individual plant species in biofiltration systems, with two notable exceptions: Bratieres *et al*. (2008) and Read *et al*. (2008). These two studies investigated a range of plant species, varying in size from rushes to large shrubs or small trees, indigenous to southeastern Australia.

# Research programme

The seasonal performance of street tree species in biofiltration systems is largely unknown. A study was designed to assess the combined performance of street trees and tree soils as part of an integrated urban stormwater treatment system. The proposed treatment system could be retrofitted into most urban streets, either at the time of tree replacement, or to amend an existing planting. Stormwater from the road and footpath is directed along the gutter and into the biofiltration system. The soil surface is set at a designed depth below the surrounding surfaces, referred to as the extended detention depth, allowing stormwater to fill this space during rain events. The systems are designed so that if the detention depth is filled, additional stormwater is bypassed into the conventional stormwater management systems to avoid flooding.

# Materials and methods

The experiment was designed to evaluate both tree growth responses and also the efficacy of nutrient removal of these biofiltration systems. Trees were grown outdoors in experimental biofiltration systems, constructed with 240 mm diameter columns, cut into 600 mm lengths. The constructed soil profiles were 500 mm deep with 10% (v:v) composted green waste added to the surface 200 mm. The three soils used were sands with saturated hydraulic conductivities (SHC) of 4, 95 and 170 mm $h^{-1}$ and the soils are referred to as low, medium and high SHC soil respectively. The hydraulic conductivity of the slowest draining soil was below the range (20–1000 mm $h^{-1}$) stipulated in the Australian Standard AS 4419 'Soils for landscaping and garden use' (Standards Australia, 2003).

The four species selected are common in urban landscapes in southern Australia (Frank *et al*., 2006) and three are Australian species. The tree species chosen come from a range of climates and environments and were chosen in part to investigate innate differences in response to the regular inundation that would be expected in biofiltration systems. The evergreen trees were planted in late March to early April 2003 and the deciduous trees in June 2003. The application of simulated runoff commenced in September of the same year.

The trees were irrigated using tapwater or a model stormwater solution and compared to unplanted, control profiles. The profiles received weekly applications of approximately 100 mm depth of either tapwater or stormwater. The chemical composition of the simulated stormwater was adapted from one devised by Davis *et al*. (2001) and included 2 mg $L^{-1}$ $NO_3^-$-N, 4 mg $L^{-1}$ organic-N and 0.6 mg $L^{-1}$ phosphate-P as well as a heavy metal (copper) and dissolved solids (sodium chloride and magnesium chloride). As suspended solids were not included in the synthetic stormwater the implications of surface clogging and changes in hydraulic performance over time were not investigated.

The model soil profiles were raised off the ground, allowing collection of leachate following simulated runoff events. An irrigation system was used to deliver the simulated runoff events. All profiles received a volume of tapwater via a microspray within a 500 mL plastic food container, and the addition of stormwater concentrate in this container prior to the system running created the simulated stormwater solution.

Data collected during the experiment included final above-ground plant biomass as well as soluble nitrogen and phosphorus concentration of the leachate over time. For above-ground biomass measurements all trees were harvested at the completion of the experiment, oven dried (70ºC for 48 hours) and weighed. Sampling of leachate from the constructed profiles for nutrient analysis was undertaken from December 2003 until December 2004. On 10 occasions during the 13-month period the leachate was collected from the base of the systems for two hours after a simulated runoff event. Filtered (0.45 µm) samples were analysed for $NO_x$ and FRP using colorimetric methods and an Alpkem (Perstorp Analytical) segmented flow autoanalyser. In some instances, typically in higher evaporative demand months towards the end of the experiment, all of the applied water was retained within the soil and no leachate drained from the profiles. The concentration was recorded as a missing value.

Analysis of variance (ANOVA) was used to make overall comparison between treatment means and differences were recorded as significant at the 5% level ($p<0.05$). Paired comparisons were made using the least significant difference (LSD). For the vegetation growth data n=8 and for the nutrient concentration of leachate from the biofiltration systems data n=3.

# Results

## Tree growth

All four tree species grew well in all three soils, including one chosen for its low, and potentially growth limiting, drainage rate. Above-ground growth of *C. salignus*, *L. confertus* and *P. orientalis* was increased when the irrigation was with the model stormwater solution rather than tapwater (Table 1). *E. polyanthemos* growth was similar with tapwater and stormwater applications in the low and high SHC soils.

**Table 1** Above-ground dry weight (g): species, soil and water quality interaction.

| Species | Soil and water quality[yz] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low SHC | | | | Medium SHC | | | | High SHC | | | |
| | Tapwater | | Stormwater | | Tapwater | | Stormwater | | Tapwater | | Stormwater | |
| *C. salignus* | 136 | b | 265 | fg | 168 | cd | 266 | fg | 133 | b | 233 | fg |
| *E. polyanthemos* | 174 | cd | 177 | cd | 149 | bcd | 243 | fg | 131 | b | 159 | bcd |
| *L. confertus* | 147 | bcd | 273 | g | 155 | bcd | 255 | fg | 129 | b | 219 | ef |
| *P. orientalis* | 86 | a | 182 | de | 85 | a | 150 | bcd | 89 | a | 143 | bc |

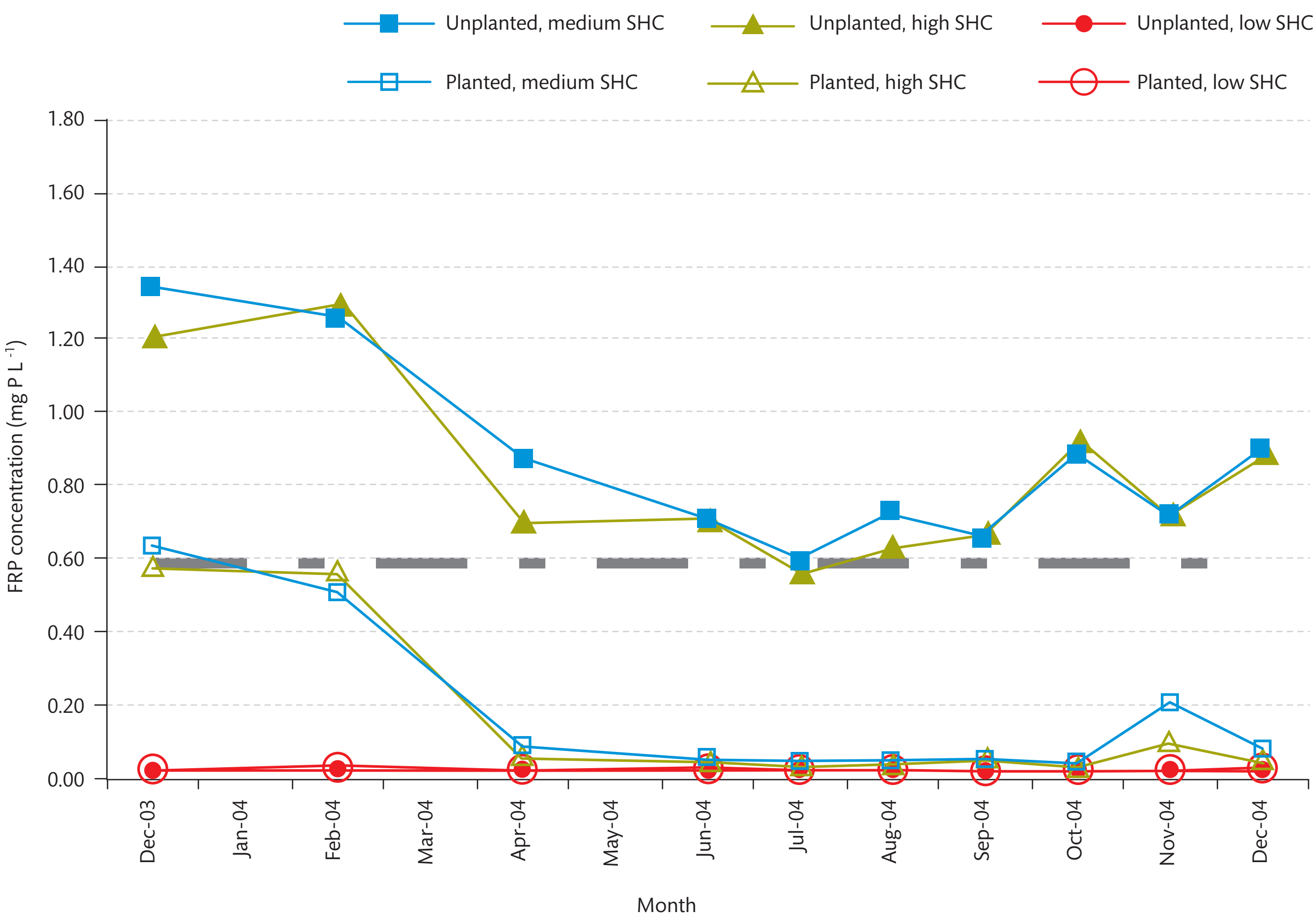
[y] Means followed by the same letter down the column and across the row are not significantly ($p<0.05$) different
[z] Means are back $\log_e$ transformed

While successful tree growth has been confirmed, the systems must also treat stormwater to successfully function in terms of biofiltration. This study focused on nutrient removal, a component of stormwater treatment.

## Nutrient removal

Compared to unplanted controls, the presence of trees resulted in significant reductions of soluble nitrogen and phosphorus concentration of leachate. The pattern of FRP concentration of leachate over time was similar between the unplanted and planted profiles (Figure 1). The leachate concentration of FRP was higher during the warmer months and in particular early in the experiment. The unplanted low SHC soil profiles were very effective in reducing the FRP concentration of stormwater. Conversely, FRP seemed to be generated within the unplanted, medium and high SHC soil profiles with higher concentrations of the leachate than the input stormwater during most events (Figure 1).

**Figure 1** FRP concentration (mg P $L^{-1}$) of leachate over time from planted and unplanted profiles receiving stormwater. The dashed, horizontal line indicates the stormwater input concentration.



The effectiveness of planted profiles at reducing the FRP concentration of stormwater was variable. The low SHC soil planted profiles greatly reduced the FRP concentration of stormwater input for all events (Figure 1). The medium and high SHC soil planted profiles had little effect at the start of the experiment, with leachate FRP concentrations similar to the input stormwater. However, following the first summer, good reductions of FRP concentrations were achieved from profiles with these two soils (Figure 1).

During the first few months of the experiment the leachate FRP concentration was high from systems planted with all four species (Figure 2). During winter (June to August) the FRP concentration of leachate from the profiles with the deciduous species was relatively similar to the leachate from those planted with evergreen species. The spike of FRP in late spring (November 2004, Figure 1) was due to high concentrations in leachate from *P. orientalis* profiles (Figure 2).

The pattern of $NO_x$ concentration of leachate over time was generally similar in both the unplanted and planted profiles (Figure 3). The leachate concentration of $NO_x$ was typically higher during the warmer months. The spike observed in July is most likely an artefact of soil core sampling undertaken prior to leachate sampling.

The $NO_x$ concentration of leachate from the planted profiles was less than from unplanted profiles (Figure 3). $NO_x$ was consistently generated in the unplanted profiles with the leachate having higher concentrations than the stormwater input during all events. The effectiveness of planted profiles in reducing the $NO_x$ concentration of stormwater was variable. On all occasions, the planted, low SHC soil profiles had lower concentrations of $NO_x$ in leachate than the stormwater input. The performance of the planted, medium and high SHC soil profiles was less consistent, with $NO_x$ being produced during late spring and summer (Figure 3). During the cooler months the concentration of $NO_x$ in stormwater was reduced by biofiltration through the planted, medium and high SHC soil systems.

The effect of species on the $NO_X$ concentration of leachate during the experiment was not significant (Figure 4, high SHC soil profiles shown).

**Figure 2** The effect of species on FRP concentration (mg P $L^{-1}$) of leachate from medium SHC soil profiles receiving stormwater. The horizontal dashed line represents the stormwater input concentration.

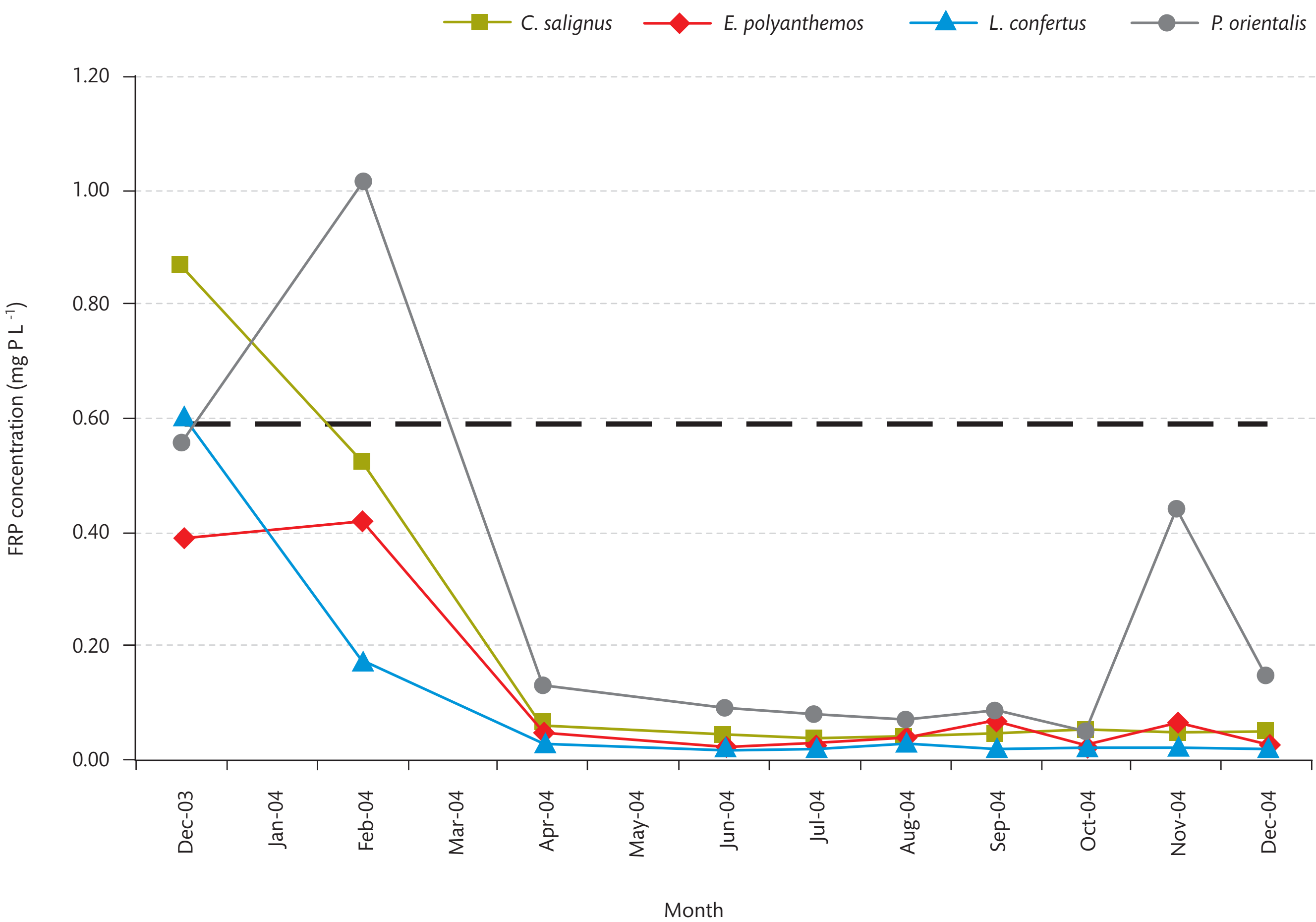


Figure 3 NOx-N concentration (mg N L$^{-1}$) of output leachate over time from profiles receiving stormwater. The dashed horizontal line represents the stormwater input concentration.

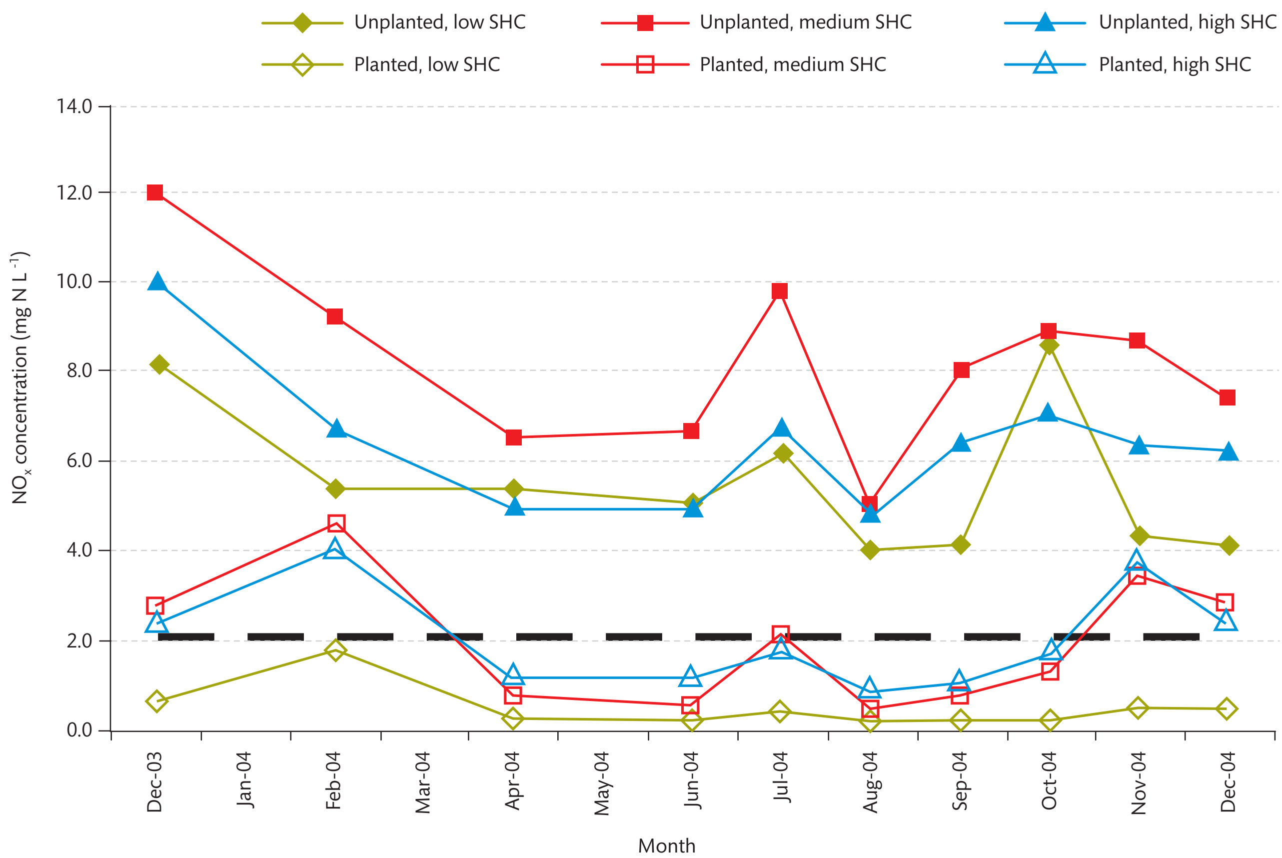
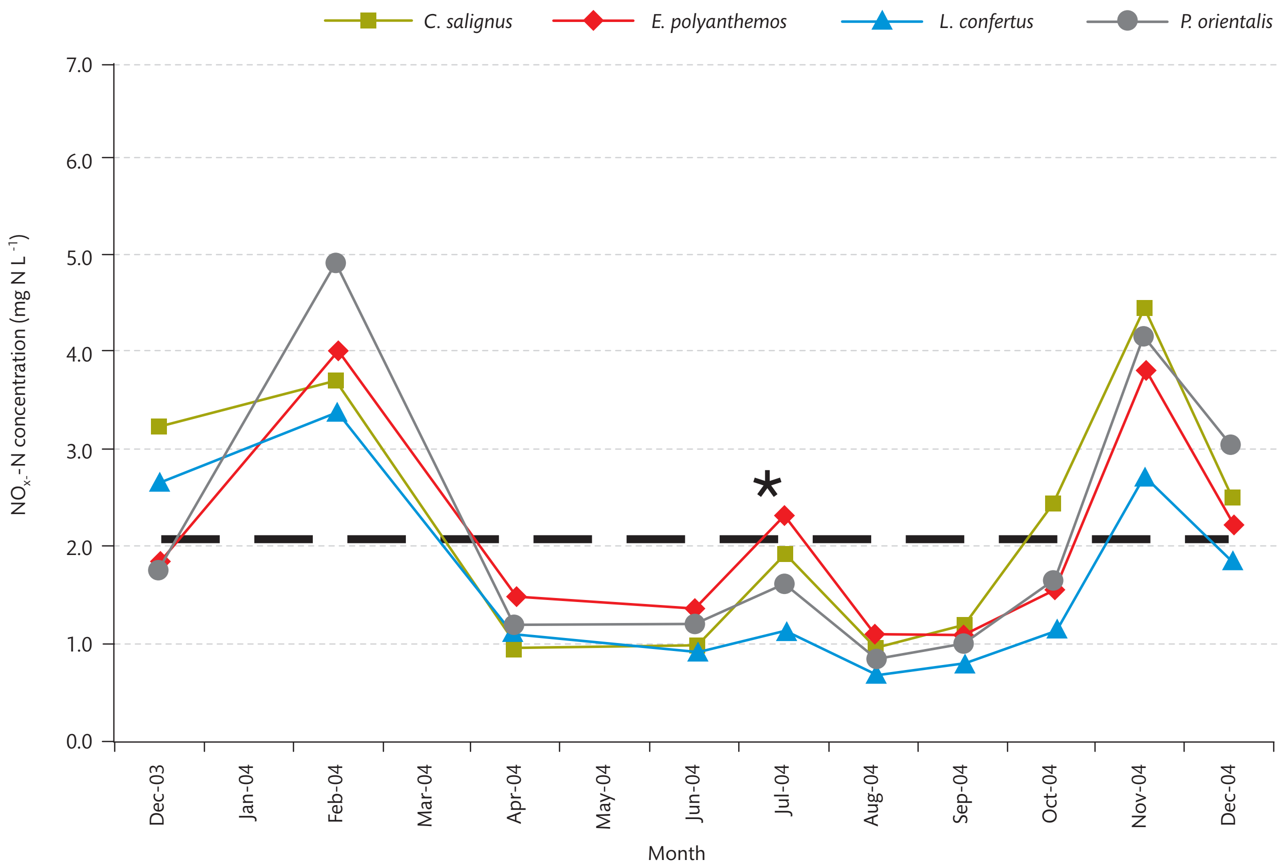



Figure 4 The effect of species on NOx-N concentration (mg N L$^{-1}$) of output leachate from high SHC soil profiles receiving stormwater. The dashed horizontal line represents the stormwater concentration. * the spike observed in July is most likely due to an experimental artefact (soil cores were taken prior to leachate sampling for root and soil analysis).



# Discussion

## Tree growth

The trees grew well in this experiment and soil selection was not critical for plant growth with regular exposure to small-sized runoff events. The low saturated hydraulic conductivity of the low SHC soil used in the experiment would not meet AS 4419–2003 guidelines and these soils may have been expected to have poor aeration. The trees grown in the low SHC soil performed well. However, further field evaluation is required to confirm that such soils would be suitable for tree growth. The rate of water infiltration into and percolation through the constructed profiles was variable and not necessarily reflective of the different saturated hydraulic conductivity of the three experimental soils (data not shown). The low SHC soil profiles did drain more slowly than the medium and high SHC soil profiles.

As a growing medium for trees, the coarse-textured soils used in biofiltration systems inherently have low levels of available nutrients and water. The addition of organic matter to similar sandy soils is common practice in constructing designed tree soils. Greater growth of the trees that received stormwater than tapwater confirms that the systems studied had low levels of nutrition.

## $NO_X$ concentration of leachate

The $NO_x$ concentration of leachate from planted systems was higher in warmer months. A positive correlation between $NO_x$ concentration of leachate from biofiltration systems and temperature has been reported (Blecken *et al.*, 2010). Averaged over time, the experimental street tree biofiltration systems reduced the $NO_x$ concentration of stormwater by 2 to 78% for the various filtration media. Street trees grown in the two faster-draining soils were not effective at reducing N concentration; however, load removal was adequate (data not shown). This reduction in $NO_x$ concentration is within reported ranges (Davis *et al.*, 2006; Henderson *et al.*, 2007; Bratieres *et al.*, 2008; Read *et al.*, 2008). Permanently saturated zones designed at the base of biofiltration systems can promote denitrification and increase nitrogen removal performance (Kim *et al.*, 2003).

## FRP concentration of leachate

The FRP concentration of stormwater was reduced by an average of 70 to 96% following biofiltration through street tree systems with various filtration media. These reductions are similar to those reported in the literature (Bratieres *et al.*, 2008, Read *et al.*, 2008).

## Seasonal patterns of nutrient concentration of leachate

Seasonal patterns of nutrient uptake capacity have been reported for some trees, with maximum rates typically coinciding with active growth periods (Roy and Gardner, 1945, Weinbaum *et al.*, 1978; Muñoz *et al.*, 1993). It was therefore anticipated that nutrient removal performance would be low during winter while the trees were dormant or growing slowly. The peaks in nutrient concentration of leachate from planted profiles occurred during summer and often corresponded to periods when higher water volumes were retained in the biofiltration systems (data not shown), suggesting that the soil was dry. This seasonal pattern of $NO_x$ and FRP concentration was also observed in the unplanted profiles with considerable leaching of nutrients during summer. This suggests that the soil may be behaving as a larger source of nutrients during these times. That is, the mineralization of organic matter is higher during the summer in response to higher temperatures (Gessler *et al.*, 1998) or possibly increased soil drying and wetting.

## Organic amendment of biofiltration media

Substantial leaching of nitrogen and phosphorus from unplanted soil profiles was found for the duration of this experiment. Despite the potential increase in cation exchange capacity, caution is required if biofiltration media are to be amended with organic matter. In response to high levels of nutrient leaching from organic matter amended soils, Bratieres *et al.* (2008) recommended that biofiltration soils are not amended. Further field testing is required to ascertain the impact of this recommendation on the long-term growth of street trees and stormwater treatment performance.

## Species selection for biofiltration systems

Four street tree species with different waterlogging tolerances were evaluated in this study to determine differences in nutrient removal performance. Species selection was not essential to maximize nutrient removal performance of biofiltration systems. The evergreen and deciduous species performed similarly during winter, when the latter had lost leaves. This raises interesting questions about root function and nutrient uptake in dormant trees. *P. orientalis* was less effective at reducing the phosphorus concentration of leachate during the final months of the experiment, although phosphorus load reduction was adequate (data not shown). This reduced performance is possibly related to stresses caused by more severe drying of soil columns in late spring and summer. Further field evaluation is required to investigate the effect of water stress on stormwater treatment performance and the likelihood of it occurring in practice. The ability of trees to withstand drought may be an important selection criterion which requires further evaluation.

Biodiversity of vegetation within our cities is important and street tree selection should not be based on a single criterion. Therefore it is a positive finding that under these experimental conditions the differences in nutrient removal performance between the four species were not large and the planting of any one particular species is not recommended. However, it is acknowledged that the lack of differences reported in this study may reflect the regime of simulated runoff events applied in this study, which may not have been sufficiently large to impose significant deoxygenation stress on the trees.

While the tree species studied behaved similarly, it is important to reiterate that for removing nutrients from stormwater vegetation is a critical component of these systems. Newly planted biofiltration systems will initially behave largely as unvegetated systems, until the root systems have developed sufficiently to colonize large proportions of the filtration medium. Nitrogen and phosphorus leaching, in terms of concentration, was still occurring in the experimental systems nine months after planting and so these systems will take some time to perform effectively. Good post-planting practices are important to ensure rapid tree establishment in these systems. As with traditional street tree planting, irrigation is most likely the most critical aspect of post-planting maintenance. To avoid water deficit stress, additional irrigation may be required until the tree root systems have established. To optimize tree establishment, the scheduling of irrigation should be proactive rather than reactive (Harris, 1998). The frequency of irrigation post-planting is more important than the volume applied (Gilman *et al*., 1998) due to the small root ball volume and the low water holding capacity of fast-draining biofiltration media. To minimize any nutrient leaching from these newly established systems, care must be taken to apply irrigation volumes which can be fully retained within the soil profile.

## Conclusions

Trees in urban built areas can contribute in many ways to sustainable stormwater management. The novel use of structural soils to form a stormwater reservoir for urban tree plantings shows promise (Bartens *et al*., 2009). In the model biofiltration systems used in this research, four common street tree species grew well. Species selection did not appear to be an important element in terms of system success. The one deciduous species behaved similarly to evergreen species, in terms of soluble nitrogen and phosphorus removal, during their dormant period. After the initial summer, the biofiltration systems were successful in reducing FRP concentration. The performance of the systems in reducing $NO_X$ concentration was more variable, and during the warmer months $NO_X$ was generated in the medium and high SHC soil profiles. This work shows that street trees have the potential to be effective elements in urban biofiltration systems and that field-level evaluation of these systems is required to further elucidate the role of such systems in urban stormwater treatment. Design modifications may be required, however, if consistent reductions in $NO_x$ concentration are required.

## References


BARTENS, J., DAY, S.D., HARRIS, J.R., DOVE, J.S. AND WYNN, T.M. (2008). Can urban tree roots improve infiltration through compacted subsoils for stormwater management? *Journal of Environmental Quality* **37**, 2048–2057.

BARTENS, J., DAY, S.D., HARRIS, J.R., WYNN, T.M. AND DOVE, J.E. (2009). Transpiration and root development of urban trees in structural soil stormwater reservoirs. *Environmental Management* **44**, 646–657.

BLECKEN, G.-T., ZINGER, Y., DELETIC, A., FLETCHER, T.D., HEDSTRÖM, A. AND VIKLANDER, M. (2010). Laboratory study on stormwater biofiltration: Nutrient and sediment removal in cold temperatures. *Journal of Hydrology* **394**, 507–514.

BLECKEN, G.-T., ZINGER, Y., MUTHANNA, T.M., DELETIC, A., FLETCHER, T.D. AND VIKLANDER, M. (2007). The influence of temperature on nutrient treatment efficiency in stormwater biofilter systems. *Water Science and Technology* **56**, 83–91.

BRATIERES, K., FLETCHER, T.D., DELETIC, A. AND ZINGER, Y. (2008). Nutrient and sediment removal by stormwater biofilters: a large-scale design optimisation study. *Water Research* **42**, 3930–3940.

DAVIS, A.P., SHOKOUHIAN, M., SHARMA, H. AND MINAMI, C. (2001). Laboratory study of biological retention for urban stormwater management. *Water Environment Research* **73**, 5–14.

DAVIS, A.P., SHOKOUHIAN, M., SHARMA, H. AND MINAMI, C. (2006). Water quality improvement through bioretention media: nitrogen and phosphorus removal. *Water Environment Research* **78**, 284–293.

DAY, S.D., DOVE, J.E., BARTENS, J. AND HARRIS, J.R. (2008). Stormwater management that combines paved surfaces and urban trees. *In:* Reddy, K.R., Khire, M. and Alshawabkeh, A.N. (eds.) *Geosustainability and Geohazard Mitigation: Proceedings of Selected Sessions of GeoCongress 2008*. March 9-12, New Orleans, Louisiana. Geotechnical

Special Publication No. 178. pp. 1129-1136.
FRANK, S., WATERS, G., BEER, R. AND MAY, P. (2006). An analysis of the street tree population of Greater Melbourne at the beginning of the 21st century. *Arboriculture & Urban Forestry* **32**, 155–163.
GESSLER, A., SCHNEIDER, S., VON SENGBUSCH, D., WEBER, P., HANEMANN, U., HUBER, C., ROTHE, A., KREUTZER, K. AND RENNENBERG, H. (1998). Field and laboratory experiments on net uptake of nitrate and ammonium by the roots of spruce (*Picea abies*) and beech (*Fagus sylvatica*) trees. *New Phytologist* **138**, 275–285.
GILMAN, E.F., BLACK, R.J. AND DEHGAN, B. (1998). Irrigation volume and frequency and tree size affect establishment rate. *Journal of Arboriculture* **24**, 1–9.
HARRIS, R. (1998). Irrigation of newly planted street trees. *In:* Neely, D. and Watson, G. (eds.) *The Landscape Below Ground II*. International Society of Arboriculture, San Francisco, California, pp. 225–232.
HATT, B.E., FLETCHER, T.D., WALSH, C.J. AND TAYLOR, S.L. (2004). The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams. *Environmental Management* **34**, 112–124.
HENDERSON, C., GREENWAY, M. AND PHILLIPS, I. (2007). Removal of dissolved nitrogen, phosphorus and carbon from stormwater by biofiltration mesocosms. *Water Science and Technology* **55**, 183–191.
KIM, H., SEAGREN, E.A. AND DAVIS, A.P. (2003). Engineered bioretention for removal of nitrate from stormwater runoff. *Water Science and Technology* **75**, 355–367.
MUÑOZ, N., GUERRI, J., LEGAZ, F. AND PRIMO-MILLO, E. (1993). Seasonal uptake of $^{15}$N-nitrate and distribution of absorbed nitrogen in peach trees. *Plant and Soil* **150**, 263–269.
READ, J., WEVILL, T., FLETCHER, T. AND DELETIC, A. (2008). Variation among plant species in pollutant removal from stormwater in biofiltration systems. *Water Research* **42**, 893–902.
ROY, W.R. AND GARDNER, F.E. (1945). Seasonal absorption of nutrient ions by orange trees in sand culture. *Proceedings of the Florida State Horticultural Society* **58**, 25–36.
STANDARDS AUSTRALIA (2003). *Australian Standard: Soils for landscaping and garden use AS 4419–2003*. Homebush, NSW.
STOVIN, V.R., JORGENSEN, A. AND CLAYDEN, A. (2008). Street trees and stormwater management. *Arboricultural Journal* **30**, 297–310.
TAYLOR, S.L., ROBERTS, S.C., WALSH, C.J. AND HATT, B.E. (2004). Catchment urbanisation and increased benthic algal biomass in streams: linking mechanisms to management. *Freshwater Biology* **49**, 835–851.
WALSH, C. J. (2004). Protection of in-stream biota from urban impacts: minimise catchment imperviousness or improve drainage design? *Marine and Freshwater Research* **55**, 317–326.
WEINBAUM, S.A., MERWIN, M.L. AND MURAOKA, T.T. (1978). Seasonal variation in nitrate uptake efficiency and distribution of absorbed nitrogen in non-bearing prune trees. *Journal of the American Society for Horticultural Science* **103**, 516–519.
XIAO, Q. AND MCPHERSON, E.G. (2002). Rainfall interception by Santa Monica's municipal urban forest. *Urban Ecosystems* **6**, 291–302.
XIAO, Q., MCPHERSON, E.G., JUSTIN, S.L., GRISMER, M.E. AND SIMPSON, J.R. (2000). Winter rainfall interception by two mature open-grown trees in Davis, California. *Hydrological Processes* **14**, 763-784.

# Quantifying the cooling benefits of urban trees


## Abstract

It is well known that trees can help cool cities because of the evapotranspiration of water from their leaves. However, because of the large number of factors that can affect this, such as temperature, relative humidity and soil moisture, there is no typical value of evapotranspiration for urban trees. Nor is it inexpensive or easy to measure evapotranspiration. This paper shows that because of the physics of gas flow, the rate of transpiration should be proportional to the photosynthetic rate and hence to the growth rate of a tree. Calculations using data from the literature and our own experimental results give support to this theory and suggest that, following validation and calibration, it should be possible to experimentally determine the cooling performance of urban trees merely by finding out how fast they are growing. The model also suggests that most ways of maximising growth – growing trees singly, using faster-growing species, giving trees large rooting spaces and urban soils, and providing irrigation – but not applying nitrogen fertiliser, should optimise their cooling performance. Research in this area could be carried out inexpensively and easily, and can involve a wide range of people.


## Introduction


**Keywords:**

cooling, evapotranspiration, trees, growth


It is well known that urban trees provide many physical benefits to cities: they sequester carbon, reduce noise, absorb particulate pollution, provide cooling and shade, and reduce storm runoff. The effects of trees on the urban environment have therefore been extensively studied, not least in the USDA Forest Service survey of the extent and effects of the urban forest of Chicago (McPherson *et al*., 1994). This research has led to the development of the UFORE (Urban Forest Effects) and i-Tree models, which can be used to estimate the financial benefits of urban trees.

The difficulties in quantifying the benefits of trees in this way cannot be overestimated. It is impossible to experimentally compare identical cities with and without trees, and it is extremely difficult and expensive to set up large-scale experiments. Researchers have had to rely on two strategies. They have carried out small-scale surveys and experiments and scaled up from there to quantify some benefits, and they have used physical and mathematical modelling to estimate others. Carbon storage and sequestration rates have been estimated for different types of tree stands (Rowntree and Nowak, 1991) by combining tree surveys with forestry figures for the growth rates of trees. The ability of trees to absorb particulate pollution, in contrast, has largely been estimated by modelling the flows of air and impact of small particles on leaves. In such a complex system as airflow in a city the results of such modelling cannot be very reliable, though this effect has been separately quantified by McDonald *et al*. (2007), who compared the levels of radioactivity beneath tree stands and areas of grass caused by the deposition of particles to which radon readily becomes attached. They combined their finding that dry deposition was three times higher in trees with aerodynamic modelling to estimate that the tree cover of the West Midlands reduced $PM_{10}$ pollution levels by 4% but that of Glasgow, by only around 2%.

The reduction in rainfall runoff is extrapolated from the results of small-scale experiments (McPherson *et al*., 1994) that investigated the interception of rainfall by tree canopies, though these studies did not actually measure the runoff itself. We are currently finding that other factors, such as the presence of planting holes and other permeable surfaces, reduce runoff by even more than their estimates would suggest.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The effect of trees on reducing the cooling and heating costs of buildings by providing summer shade and winter shelter from wind was also calculated by combining small-scale experimental studies (Huang *et al*., 1987) with larger-scale modelling (McPherson *et al*., 1994). Finally, the effect of trees in cooling the air over the whole city and hence reducing the urban heat island effect was quantified by large-scale climate studies; air temperatures in different parts of the city were related to the tree cover (McPherson *et al*., 1994).

All of this hard work means that we now have good estimates of the overall benefits of urban trees, at least in the USA, which have provided the evidence base that has driven extensive urban tree planting schemes such as that in New York. However, despite its success this research, concentrating as it does on the effects of 'typical' trees and areas of urban forest, has failed to answer many of the questions that European (and indeed American) practitioners really need to know before they can successfully green their cities. Are trees actually better than other types of vegetation, especially grassland, at providing cooling? Which species of trees provide the greatest cooling benefits? Is it better to have many small or fewer large trees? What effect will soil conditions and irrigation have on the cooling benefits that trees confer? And how will climate change affect the growth and cooling effectiveness of trees? Here I show that, despite the apparent complexity of the situation, understanding the physics of the urban climate and the physiology of trees can give us an incredibly inexpensive and simple method of answering these questions. By involving not only scientists but also tree professionals and the general public in new research projects based on this method, we can rapidly improve our knowledge of the benefits of urban trees and revolutionise people's perceptions of the role of science in our lives.

## Urban trees and cooling

The effect of trees on urban climate is ideally approached by comparing the energy balance of rural and urban areas. Though heating, air conditioning and transport all produce energy in the city, this is a surprisingly small component of their heat balance; anthropogenic heat output is around 50 $Wm^{-2}$. Except in winter this is dwarfed by the energy we receive from the sun, which even in the UK peaks at over 800 $Wm^{-2}$. The difference between town and country is therefore mostly due to what happens to the sun's energy in the two environments.

In rural areas, around 20–25% of the incoming short-wave radiation is reflected back into the sky by grass and 15% by trees. Of the energy that is absorbed, over a half is often used to evaporate water from leaves, a process known as evapotranspiration (Oke, 1987). This cools the vegetation, so it radiates little long-wave radiation and even less energy remains to heat the air by convection and to heat the soil by conduction.

In cities, where vegetation has been replaced by buildings and roads, the energy balance is dramatically altered. Dark man-made materials have a lower albedo than vegetation, so around 15% of the sun's radiation is reflected, and even less in high-rise cities where light is reflected down into urban 'canyons'. Almost all of the absorbed energy is used to heat up the dry roads and roofs, where it is either stored in bricks and mortar or heats the air above, raising daytime surface and air temperatures well above that of the surrounding countryside. At night the situation can become worse, since cities also cool down more slowly; there is more heat stored in the buildings to dissipate, there is more pollution to trap long-wave radiation, and within urban canyons less of the cool sky is visible, so less radiation can escape. The result is the development of a summer urban heat island which can cause a rise in air temperatures of up to 7°C in large cities (Wilby, 2003).

It is easy to understand that incorporating vegetation into cities should reduce the urban heat island, largely because it increases evapotranspirational cooling. Unfortunately, though, it appears at first glance to be extremely difficult to quantify how great this effect will be, since evapotranspiration can be affected by a large number of interacting factors. First, it will depend on the weather: on the temperature, relative humidity, the amount of incoming radiation, windspeed and air turbulence. It will also depend on the properties of the vegetation itself: on the crown area, leaf area index, height of the leaves, stomatal conductance, and hydraulic resistance of the shoot and root. Finally, it will depend on the soil conditions: on its dryness, compaction and hydraulic conductivity. If we had to measure all of these factors it would be impossible to make sensible estimates for what is occurring even for smaller plants.

## Estimating and measuring evapotranspiration of vegetation

To estimate the evapotranspiration of large areas of vegetation, environmental physicists and micrometerologists have approached the problem from a purely physical standpoint; they have considered the energy changes at the surface of evapotranspiring vegetation. The rate of evaporation from a wet surface exposed to air which is not fully saturated is given by the Penman equation (Monteith and Unsworth, 1990).

$$\lambda E = \frac{mR_n + \rho c\,(\delta e)\,g_a}{m + \gamma} \qquad 1)$$

where $\lambda$ is the latent heat of water (around 2.43 MJ $kg^{-1}$), E is the rate of loss of water per unit area (kg $m^{-2}s^{-1}$), m is the slope of the saturation vapour pressure curve (Pa $K^{-1}$), $R_n$ is the net irradiance (W $m^{-2}$), $\rho$ is the density of air ($kgm^{-3}$), c is the specific heat of air (J $kg^{-1}$ $K^{-1}$), $\delta\varepsilon$ is the vapour pressure deficit (or difference between vapour pressure of air and saturation) (Pa), $g_a$ is the conductance of the air around the surface (m $s^{-1}$) and $\gamma$ is the psychrometer constant ($c\rho/\lambda\varepsilon$) (around 66 Pa $K^{-1}$).

The Penman equation shows that water loss is the sum of two components: that due to the solar radiation heating the surface and that due to the fact that water evaporates even from unheated surfaces. As a result the rate of water loss depends predictably on the level of sunlight, on the air temperature, on the dryness of the air, on the position of the surface, and on the windspeed. However, the equation has to be modified for plants, which have lower water loss than a wet surface because of the resistance of their stomata to water loss. This results in the well-known Penman-Monteith equation (Monteith and Unsworth, 1990).

$$\lambda E = \frac{mR_n + \rho c\,(\delta e)\,g_a}{m + \gamma(1 + g_a/g_s)} \qquad 2)$$

where $g_s$ is the stomatal conductance.

By making assumptions about the way wind varies close to a rough surface and estimating the stomatal conductance of crops, agronomists can incorporate continuous measurements from weather stations into this equation to estimate the rate of water loss from a layer of well-watered grass. This is known as the reference evapotranspiration $ET_0$ (Allen *et al*., 1998).

To verify this estimate and measure actual values of evapotranspiration for different types of vegetation cover, meteorologists have devised several experimental techniques which can be used over large areas of vegetation. The most commonly used is the eddy correlation method (Oke, 1987) in which the vertical velocity and relative humidity of air is measured above the stand, and combined to calculate the upward rate of water movement. Measurements using eddy correlation confirm that the Penman-Monteith equation does accurately estimate water loss from well-watered grass (Allen *et al*., 1998). The rates of evapotranspiration from other plants have also been measured. They tend to be lower in crops with low stomatal conductance (e.g. drought-resistant crops), and higher in ones with high stomatal conductance. The three-dimensional shape of the plants is also important as this affects the canopy conductance. In low-growing grasses there is low conductance due to the barrier of still air near the ground. In isolated trees, in contrast, the conductance is much higher, since they protrude out of the boundary layer into the wind. The evapotranspiration of a range of species is calculated by incorporating a crop factor $K_C$ into the Penman-Monteith equation (Allen *et al*., 1998) where

$$E_T = ET_0 \times K_C \qquad 3)$$

Tables of crop factors are given by Allen *et al*. (1998) and tend to be around or less than 1 for most crop plants but can exceed 1 for some orchard trees.

The crop factors given are for well-watered plants. Drought reduces evapotranspiration below the reference figure, lowering $K_C$ because of the reduced conductance of the stomata as the plant shuts down. To calculate the evapotranspiration of droughted crops it is usual to reduce the evapotranspiration by a factor proportional to the matric potential of the soil (Rowell, 1994; Allen *et al*., 1998).

The results of these types of studies have proved to be reliable and extremely useful for farmers planning irrigation programmes and greenkeepers planning watering regimes for golf courses. However, they are less useful for calculating the evapotranspiration of urban trees. There are limited data for the crop factors of urban trees in the literature, and studies using eddy covariance are expensive. In any case, urban trees are rarely found in continuous stands; they are more often planted in small groups or singly. The evapotranspiration of isolated trees has in fact rarely been investigated, though the physical analysis of the meteorologists suggests that isolated urban trees should have higher rates of evapotranspiration per unit canopy area than continuous forests or grass. This is because they will encounter dry air from outside the stand, and this advection will increase evapotranspiration. This should result in what are known to meteorologists as the clothes-line and oasis effects, but the size of the increases that will result are uncertain. Some methods are therefore required to estimate or measure the evapotranspiration from individual trees.

## Estimating and measuring evapotranspiration of individual trees

Plant physiologists have devised some fairly straightforward ways of directly measuring the evapotranspiration of a plant. For small containerised plants, including small trees, it is possible to continuously monitor the weight of the plant and its pot (Kjelgren and Montague, 1998; Montgue *et al*., 2004). For larger trees this is impractical. An alternative method is to attach a porometer or IRGA to a leaf to measure its stomatal conductance (Lambers *et al*., 1998). If you also measure the leaf temperature, air temperature, atmospheric pressure, relative humidity and the leaf area of the tree you can use this result to calculate the instantaneous rate of water loss. Unfortunately, this method is expensive, time-consuming and impractical for continuous monitoring. A final method has that been devised that will allow continuous monitoring of water loss is to use sap flow meters (Pataki *et al*., 2011). These are electrically heated collars that can be attached to the trunk; they apply bursts of heating to it, warming the sap within, while the apparatus monitors the temperature higher up the trunk, allowing the velocity and hence volume flow of water up the trunk to be calculated. This technique is becoming increasingly common, having being used extensively in forests and orchards, but can be rather complicated and expensive to perform, and highly vulnerable to vandalism.

When these techniques have been applied to measure the evapotranspiration of urban trees, the results have been extremely variable. For instance Montague *et al*. (2004) found that water loss varied widely between species, and there were large differences between trees growing over grass and asphalt (Kjelgren and Montague, 1998). Similarly our measurements of *Pyrus calleryana* Chanticleer street trees (Rahman *et al*., 2011) found large differences in growth and evapotranspiration rates between trees grown in different soil conditions. We found that trees planted in Amsterdam soil had twice the rate of diameter breast height growth as ones grown in conventional tree pits, probably because the lack of soil compaction had allowed their roots to grow more rapidly. The trees in Amsterdam soil also had twice the stomatal conductance, and because of their greater crown diameter and leaf area index were transpiring at five times the rate of trees growing in conventional soil pits. At midday on sunny days they were providing some 7 kW of cooling (compared to 1.5 kW for trees in conventional tree pits), and losing heat at a rate of 1105 W $m^{-2}$, over three times that of a reference crop of grass. Finally, in their survey of trees across Los Angeles Pataki *et al*. (2011) found tenfold differences in evapotranspiration between trees, depending on their location and the level of irrigation with which they were supplied. It is plain, therefore, that there are no 'typical values' of evapotranspiration rate that can be applied to urban trees.

## The solution

Fortunately, there is a simple way of overcoming the uncertainties about evapotranspiration which is related to the way in which plants control their water loss and the physics of the movement of gases. Plants open their stomata to facilitate $CO_2$ access, which is used in photosynthesis, but this has the disadvantage that at the same time it releases water vapour. The rate of evapotranspiration of a plant is therefore directly proportional to the rate at which carbon dioxide enters: in other words its photosynthetic rate. The water use efficiency of photosynthesis in conventionally photosynthesising $C_3$ plants can be given by the equation:

$$WUE = 1.6c\ P_a / (e^*_L - e) \qquad 4)$$

(Farquhar *et al*., 1980; Sinclair *et al*., 1984). Here $P_a$ is the ambient concentration of $CO_2$ in the atmosphere, c is 1 minus the ratio of internal to external $CO_2$ concentration ($(1 - P_i / P_a)$, which is around 0.3 for conventionally photosynthesising $C_3$ plants), $e^*_L$ is the saturation vapour pressure at leaf temperature and e is the vapour pressure of the atmosphere. Equation 4 shows that the water use efficiency must be pretty similar for all trees. They could increase efficiency by keeping their leaves cooler (and so reduce $e^*_L$). They could also increase the level of the carbon fixing enzyme Rubisco (and hence the nitrogen concentration) in their leaves, so reducing $P_i$ and increasing c. However, both of these effects are limited. Consequently, the water use efficiency of conventionally photosynthesising $C_3$ plants (such as trees and temperate grasses) is remarkably constant, from 2 to 4 x $10^{-3}$ moles $CO_2$ assimilated per mole $H_2O$ lost (Farquhar *et al*., 1980). For each mole of $CO_2$ assimilated, 250 to 500 moles of $H_2O$ are lost (Field *et al*., 1983).

How can this help us? Continuous monitoring of photosynthesis is impractical, but we can readily measure tree growth and carbon sequestration over the season. We also need to be able to relate this to photosynthesis. Studies on the net and gross primary productivity of forests (Waring *et al*., 1998) and experimental investigations on young poplar and Douglas fir trees (Rippulone *et al*., 2004) have shown that approximately 50% of photosynthesis is converted into biomass production so that the water use efficiency in terms of dry biomass production $WUE_B$ is 1.5 to 2.5 g biomass $kg^{-1}$ water loss. Inverting the equations provides the following estimates for water loss per unit of above-ground biomass sequestration.

$$\text{Water loss} = 0.4 \text{ to } 0.66 \text{ tonnes } H_2O\ kg^{-1} \text{ biomass sequestered} \qquad 5)$$

Since evaporation of water requires 2.43 x $10^3$ J $g^{-1}$, it is also straightforward to calculate the cooling provided.

$$\text{Cooling} = 1.0 \text{ to } 1.6 \times 10^9\ J\ kg^{-1} \text{ biomass sequestered} \qquad 6)$$

## Discussion

The theory seems simple and compelling, but how realistic are these figures? There are two ways of judging these estimates: by comparing the predicted water losses with actual measurements and by comparing cooling rates with actual measurements.

Consider the water losses of a short rotation coppice, sequestering biomass at the rate of 10 tonnes $ha^{-1}a^{-1}$ or 1.0 kg $m^{-2}a^{-1}$. It should lose water at a rate of 0.4 to 0.66 tonnes $H_2O$ $m^{-2}a^{-1}$ or over a 180 day season at a rate of 2.2 to 3.3 mm $d^{-1}$, which is in good agreement with measured values (Guidi *et al*., 2008). This water loss would provide a mean cooling over a 16 hour day of 1.0 to 1.6 x $10^9$/(180 x 16 x 60 x 60) = 96 to 154 W $m^{-2}$. Peak cooling rates are probably around 4 times this value: 380–610 W $m^{-2}$, which is somewhat lower than the values we obtained for our fast-growing *Pyrus* trees. Contrast that with a typical area of deciduous forest that is sequestering dry mass at a rate of 2 tonnes $ha^{-1}a^{-1}$ or 0.2 kg $m^{-2}a^{-1}$. It will provide cooling at a rate of 2 to 3.6 x $10^8$ J $m^{-2}a^{-1}$. Given that cooling only occurs during the day when the forest is in leaf this means a mean daily cooling rate of 2.0 to 3.6 x $10^8$/(180 x 16 x 60 x 60) = 19 to 31 W $m^{-2}$. Peak cooling rates are probably around 4 times this value: 75–125 W $m^{-2}$, which is around 10–16% of UK peak radiation input, similar to the values obtained for forests (Oke, 1987).

What about urban trees? Using equations 5 and 6, and the figures for the sequestration rates of areas of urban forests from Rowntree and Nowak's (1991) study, an average stand of trees, sequestering carbon at 0.3 tons per acre, would be laying down dry biomass at a rate of 1.87 tonnes $ha^{-1}$. It would therefore have been providing an average cooling over the day during the growing season of 18–29 W $m^{-2}$. Fast-growing young stands (Type 1) would produce higher rates of cooling of 45–73 W $m^{-2}$. From their figures, the cooling of a single sugar maple can also be calculated. As its sequestration rate increases up to a peak at age 70 years of 200 pounds of carbon per year, or 90 kg, it would provide an average rate of cooling of 10–17 kW.

These results, though promising and plausible, are only estimates. The model needs to be verified and calibrated by carrying out studies in which the growth and sequestration rates of a range of urban trees are measured, and related to sap flow measurements of their annual water loss.

Assuming that the results of such a study verify the model, the implications of the theory are profound, and lead to several predictions. The first prediction is that because trees project out of the boundary layer and can grow faster than grass, trees have the potential to cool cities at many times the rate of grass swards of the same surface area. The second prediction is that isolated trees, which can capture several times more sunlight, grow several times faster and cast shade over several times the ground area than canopy trees, should provide greater cooling benefits per unit crown area. The third is that fast-growing tree species will provide greater cooling benefits than slow-growing species as long as they are kept supplied with sufficient water. This explains why fast-growing but water-demanding plane trees are planted in urban areas in Mediterranean countries, rather than drought-tolerant species. The fourth prediction, though, is that simply planting urban trees is not enough; they must also be sited and maintained in such a way as to maximise their growth rate to allow them to provide the maximum cooling benefit. Fortunately, this is something that would be welcomed in any case by tree professionals. Several techniques could be used to ensure trees perform well. They could be grown in large volumes of urban soils that resist compaction and hence allow rapid root growth. They could be grown beneath large areas of permeable paving, and pavements could be contoured in towards their planting holes to maximise the input of rainwater. Of course this would have the added advantage that it would also minimise runoff to drains. Finally, as in Mediterranean countries, they could be provided with ample irrigation, possibly from stormwater runoff. The one method of stimulating tree growth that would be unlikely to improve cooling would be to supply them with larger amounts of nitrogen fertiliser. Though this would probably improve their growth rate, it would also increase their water use efficiency, so any effect on transpiration and cooling rates would be small.

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The theory also provides us with the potential opportunity to determine the cooling power of our current tree stock merely by measuring its rate of growth and carbon sequestration. Measuring tree growth and estimating the rate of sequestration of biomass are well within the capabilities of tree professionals, and even trained members of the general public. These could then be converted to the cooling power of the trees. There is an opportunity, therefore, to develop projects countrywide to measure the environmental benefits of our trees and determine how best they can be maximised. At the same time such projects would also give a wide range of people the opportunity to become involved in citizen science and in the care of their local environment.

## References

ALLEN, R.G., PEREIRA, L.S., RAES, D. AND SMITH, M. (1998). *Crop evapotranspiration – Guidelines for computing crop water requirements* – FAO Irrigation and drainage paper 56.

FARQUHAR, G.D., VON CAEMMERER, S. AND BERRY, J.A. (1980). A biochemical model of photosynthetic $CO_2$ assimilation in leaves of $C_3$ species. *Planta* **149**, 78–90.

FIELD, C., MERINO, J. AND MOONEY, H.A. (1983). Compromises between water-use efficiency and nitrogen-use efficiency in five species of California evergreens. *Oecologia* **60**, 384–389.

GUIDI, W., PICCIONI, E. AND BONARI, E. (2008). Evapotranspiration and crop coefficient of poplar and willow short-rotation coppice used as vegetation filter. *Bioresource Technology* **99**, 4832–4840.

HUANG, J., AKBARI, H., TAHA, H. AND ROSENFELD, A. (1987). The potential of vegetation in reducing summer cooling loads in residential buildings. *Journal of Climate and Applied Meteorology* **26**, 1103–1116.

KJELGREN, R. AND MONTAGUE, T. (1998). Urban tree transpiration over turf and asphalt surfaces. *Atmospheric Environment* **32**, 35–41.

LAMBERS, H., CHAPIN III, F.S. AND PONS, T.L. (1998). *Plant Physiological Ecology.* Springer, Berlin.

MCDONALD, A.G., BEALEY, W.J., FOWLER, D., DRAGOSITS, U., SKIBA, U., SMITH, R., DONOVAN, R.G., BRETT, H.E., HEWITT, C.N. AND NEMITZ, E. (2007). Quantifying the effect of urban tree planting on concentrations and depositions of PM10 in two UK conurbations. *Atmospheric Environment* **41**, 8455–8467.

MCPHERSON, E.G., NOWAK, D.J. AND ROWNTREE, R.A. (1994). *Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project*. General Technical Report NE-186. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

MONTAGUE, T., KJELGREN, R., ALLEN, R. AND WESTER, D. (2004). Water loss estimates for five recently transplanted landscape tree species in a semi-arid climate. *Journal of Environmental Horticulture* **22**, 189–196.

MONTEITH, J.L. AND UNSWORTH, M.H. (1990). *Principles of environmental physics*. Edward Arnold, New York.

OKE, T.R. (1987). *Boundary Layer Climates, 2nd Edition.* Routledge, London.

PATAKI, D.E., MCCARTHY, H.R., LITVAK,E. AND PINCETL, S. (2011). Transpiration of urban forests in the Los Angeles metropolitan area. *Ecological Applications* **21**, 661–677.

RAHMAN, M.A., SMITH, J.G., STRINGER, P. AND ENNOS, A.R. (2011). Effect of rooting conditions on the growth and cooling ability of *Pyrus calleryana*. *Urban Forestry and Urban Greening* **10**, 185–192.

RIPPULONE, F., LAUTERI, M., GRASSI G., AMATO, M. AND BORGHETTI, M. (2004). Variation in nitrogen supply changes water-use efficiency of *Pseudotsuga menziesii* and *Populus × euroamericana*; a comparison of three approaches to determine water-use efficiency. *Tree Physiology* **24**, 671–679.

ROWELL, D.L. (1994). *Soil Science: Methods and Applications.* Longman Scientific and Technical, Harlow.

ROWNTREE, A.R. AND NOWAK, D.J. (1991). Quantifying the role of urban forests in removing atmospheric carbon dioxide. *Journal of Arboriculture* **17**, 269–275.

SINCLAIR, T.R., TANNER, C.B. AND BENNETT, J.M. (1984). Water-use efficiency in crop production. *Bioscience* **34**, 36–40.

WARING, R.H., LANDSBERG, J.J. AND WILLIAMS, M. (1998). Net primary productivity of forests: a constant fraction of gross primary production? *Tree Physiology* **18** 129–134.

WILBY, R.L. (2003). Past and projected trends in London's urban heat island. *Weather* **58**, 251–260.

# Advances in utility arboriculture research and the implications for the amenity and urban forestry sectors


## Abstract

The electricity distribution companies in the UK have a statutory obligation to provide a continuous supply of quality power, safely and efficiently. The Government and Regulatory Authorities require that the companies must try to minimise interruptions to supply caused by trees. As part of the discharge of their statutory obligations, the electricity distribution companies are undertaking research into the growth rates of trees following pruning in relation to projected changes in the UK climate in 2020 and 2050, and into the possible use of tree growth regulators to slow the rates of re-growth without harming the trees. In addition, research has been initiated into the possible development of a system of assessing trees in order to predict the likelihood of them failing, and causing supply interruptions and/or damage to apparatus in extreme adverse weather conditions. This paper describes the research projects and the results to date.

The failure of small to medium sized branches within the crowns of trees is also described; the implications of this, and the other research for the arboriculture and urban forestry sectors, is discussed.



**Keywords:**

distribution line clearance study, resilience, tree growth rates, tree growth regulator, utility space degradation



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## Introduction and background

In Britain electric utility companies are under a legal duty to maintain their overhead power line (OHPL) networks free of interruptions where reasonably practicable. Trees are one of the principal causes of unplanned service interruptions on the OHPL networks and since 2002 electric utilities have been under increasing pressure from the regulatory authorities to reduce the number of interruptions/faults that are caused by trees and other vegetation. After privatisation of the electricity industry in 1989 the trend in tree-related interruptions to supply was increasing. It reached a peak in 2004/05 when it was estimated that in the five years from 2000 20% of all interruptions on the low voltage (LV) networks and 12% of all interruptions on the high voltage (HV) networks were caused by trees (Department of Trade and Industry, DTI, 2006). In reality, the figures were probably higher as a significant number of tree-related faults may have been attributed to 'windborne materials' or 'wind and gale'.

In 2002 the British Regulator, Ofgem (Office for the Gas and Electricity Markets), and the Department for Energy and Climate Change (DECC) replaced the Electricity Safety Regulations (ESR) with the Electricity Safety, Quality and Continuity (ESQC) Regulations. Following a major storm in October 2002, when tree-caused service interruptions left millions of customers across Britain off supply for long periods of time, the regulations were amended to strengthen the obligation they place upon the electric utilities to eliminate tree-related interruptions where reasonably practicable. The amended regulations are cited as the ESQC (A) Regulations 2006.

DECC requires that the electric utilities must maintain progressive and proactive tree and vegetation management programmes. This is a reasonable expectation, but in reality, since privatisation of the electricity industry in 1989, the 14 distribution licence areas maintained tree and vegetation clearance programmes to varying degrees; some operated proactive and effective programmes, while others operated reactive programmes and did the minimum amount of tree cutting necessary, typically in response to faults. Consequently, when the

2002 Regulations and the amended 2006 Regulations came into force the licence areas were at different stages in vegetation management; some were well advanced, while others had not started proactive management programmes.

In 2006 the DECC imposed an additional obligation on the electric utilities to make their OHPL networks 'resilient' against tree and vegetation damage in 'abnormal weather conditions'. This obligation means that in addition to the routine proactive cycles of cutting to safeguard the OHPL networks throughout the normal annual weather patterns, they must, where reasonably practicable, try to secure the OHPL networks against damage from trees and vegetation during major storm events that occur periodically (i.e. storm events that have return periods of once in 10 years, 25 years, etc.). The guidance for this is found in the Electricity Networks Association (ENA) publication ETR 132 (2005).

The result of the changes to the regulations and the imposition of the 'resilience' obligation was that the budgets for utility vegetation management (UVM) were increased significantly, from about £87 million per annum across all 14 licence areas between 2004 and 2009 to £134 million per annum for the period 2010 to 2015.

It follows therefore that any developments that can assist in reducing the amount of money that has to be spent on tree cutting and enhancing the security and continuity of the supply of electricity is to be welcomed. The utility sector monitors research developments in the fields of arboriculture and forestry and implements new developments that are appropriate. However, research initiatives in arboriculture and forestry are not aimed specifically at the utility sector and it is only when a development is relevant to that sector that it is adopted, visual tree assessment (VTA) and decay detection techniques being examples.

There are specific areas where expanded knowledge would greatly assist the utilities to improve their UVM programmes. These include: (i) information on the growth rates of the most common genera of trees that occur on and adjacent to the OHPL networks; (ii) whether the growth rates of trees can be regulated to slow them down and thus extend the cutting cycle; (iii) whether a reliable system can be developed that could predict the likelihood of trees failing in abnormal weather conditions; (iv) the failure patterns of the commonly occurring trees; (v) how tree branches fail. Research into these aspects is in progress, and is described below.

It is essential that any electric utility should know with a reasonable degree of accuracy the species/genera of trees that occur most frequently on/adjacent to its OHPL networks, yet some do not have this basic information. The essential information on the OHPL networks of an electric utility can be gathered to greater than 90% confidence through a distribution line clearance (DLC) survey assessment. This is the starting point from which an effective proactive UVM programme, which can include research developments, can be developed.

## The distribution line clearance survey

This approach to analysing the OHPL networks was developed in the USA in response to continued pressure upon expenditures in line clearance (Johns and Holewinski, 1981). Essentially it involves undertaking a statistically valid random sample of the entire OHPL network and at each sample point walking 1.6 km of the line and recording the following data:*

1. The number of trees present.
2. The species/genera of tree present.
3. The number of hazard (resilience) trees present.
4. The distance between the trees and the conductors.
5. The type of work required to obtain clearance, e.g. felling or pruning.
6. The type of pruning required, e.g. top, side or overhang.
7. The lengths of any hedges or hedgerows impacting the OHPLs, i.e. linear metres.
8. The number of square metres of brush, i.e. self-seeded saplings present.

*The DLC also collects data on demographics, operating procedures, crew size and type, management of the programme and much more but this is outside the scope of this paper. From the UVM perspective what the DLC provides is a measure of the actual workload on the OHPL networks, which is accurate to greater than 90% confidence. For example it would produce typical results from a distribution network operator (DNO) with two regions as shown in Table 1.

All these data are extremely useful in facilitating the design and implementation of proactive UVM programmes. However, for the purposes of this paper the interesting data that emerges is the identification of the most frequently occurring species/genera of tree on the DNO's OHPL networks. Typically, between 60% and 70% of the trees are of five or six species.

The Central Networks (CN, now Western Power Distribution, WPD) DLC recorded a total of 89 species/genera present on

Table 1 Projected tree and brush workload on a typical electric utility's extra high voltage (EHV), high voltage (HV) and low voltage (LV) overhead power line networks.

| | Tree pruning | Tree removal | Hazard trees | Total trees | Tree line contacts | Overhang | Hedge / hedgerow (km) | Brush (ha) | % error |
|---|---|---|---|---|---|---|---|---|---|
| **Region A** | 78 000 | 31 000 | 3200 | 112 200 | 21 000 | 12 250 | 3120 | 265 | +/- 9.3% |
| **Region B** | 86 500 | 28 200 | 2950 | 117 650 | 11 200 | 10 200 | 3750 | 370 | +/- 8.4% |
| **Total** | 164 500 | 59 200 | 6150 | 229 850 | 32 200 | 22 450 | 6870 | 635 | +/- 7.2% |

These figures are an amalgamation of figures from utilities in the USA and are not figures from any UK DNO.

the OHPL networks and five genera accounted for 57% of the total trees (Environmental Consultants, 2009). These were as follows:

- Ash (*Fraxinus* spp.) – 19%
- Thorn (*Crataegus* spp.) – 13%
- Oak (*Quercus* spp.) – 10%
- Sycamore (*Acer pseudoplatanus*) – 8%
- Willow (*Salix* spp.) – 7%

Analysis of the re-growth rates of these genera following pruning provided an accurate measurement of how fast these trees grow following pruning, as shown in Figures 1 and 2.

The information on growth rates allowed CN (now WPD) to calculate how much needs to be cut from these trees to ensure that they remain clear of the conductors for the duration of the pruning cycles, which are four years on 132 kV and EHV and five years on 11 kV and LV. This information is provided in tabular form to the tree cutting contractors as part of the *Tree Management Specification* (Central Networks, 2011). This essential knowledge allows CN (now WPD) to comply with the required minimum clearances distances between its OHPL networks and trees as defined by the Energy Networks Association (ENA, 2004).

Knowing the most commonly occurring trees allows for other research to be undertaken to gather more information on those trees. By undertaking investigations of tree-caused faults when they occur to determine the species and the exact mechanism by which the tree(s) caused the fault (i.e. broken/failed branch, broken/failed trunk, tree uprooted, leaning on the line, growth, etc.) it is possible to determine if patterns emerge over time. For example is one species more prone to causing outages? What is the most common mechanism of the causes of outages? These data will then inform future pre-cutting surveys such that resources can be targeted to those trees most likely to cause outages. A Tree Fault Database to gather this information is being developed.

Figure 1 Measured mean side growth and standard deviation four years after pruning on the five most abundant genera on the CN (now WPD) OHPL networks representing 57% of the total tree population.

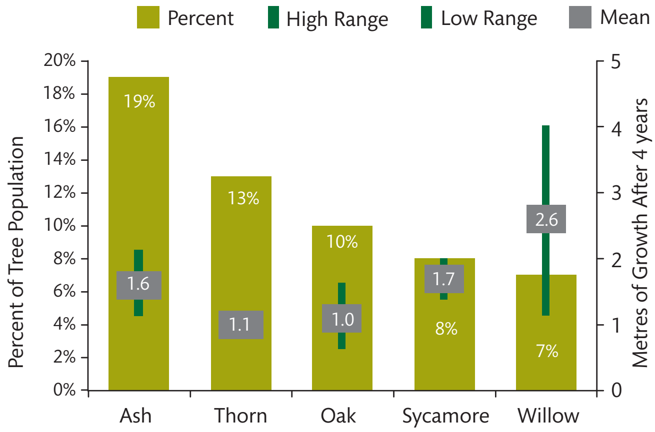
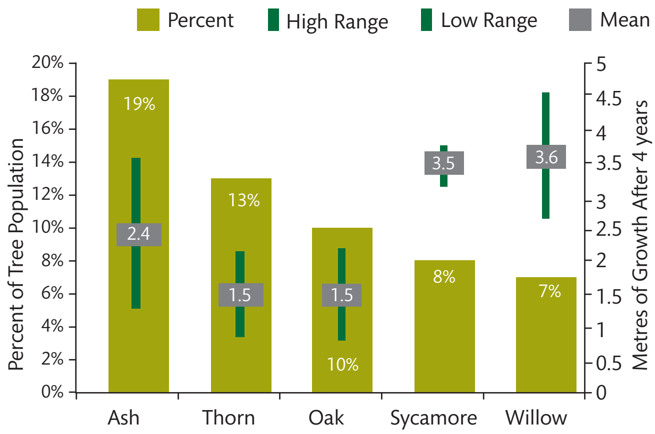



Figure 2 Measured mean top growth and standard deviation four years after pruning on the five most abundant genera on the CN (now WPD) OHPL networks representing 57% of the total tree population.



# Tree growth rates and climate change

## Background

The importance of knowing the growth rates of the most common trees on the OHPL networks has been demonstrated. However, the growth rates shown in Figures 1 and 2 above are for trees on the CN (now WPD) OHPL networks and do not represent growth rates across the whole of the UK. Nor do they take account of how the growth rates might change in response to the projected change in climate as set out in the UK Climate Impact Projections (UKCIP) (Murphy *et al.*, 2009).

Apart from the growth rate study undertaken as part of the CN (now WPD) DLC there has been little work completed studying the impact of tree growth around OHPLs and in particular the manner in which utility space (US) (i.e. the physical volume occupied by the utility apparatus and the additional space required to ensure its safe and reliable operation) is degraded by tree growth over time. Consequently, in 2008 a project was commissioned with the aim of improving our understanding of tree growth rates in relation to overhead power lines across the UK. The project is led by ADAS and funded through the Ofgem innovation fund initiative (IFI), with four DNOs representing seven licence areas and National Grid (NG) participating. The DNOs are Central Networks, CN (now WPD); Scottish Power, SP; Electricity North West, ENW (formerly United Utilities); and UK Power Networks, UKPN (formerly EDF).

## Climate change

There is much debate on the issue of climate change and the causes, but whether it is a natural cycle or man-made or both there are clear signs that the climate is changing. For example, the Meteorological Office reports that the longest thermal growing season in the 350-year daily Central England series occurred in 2000, when it extended for 328 days from 29 January to 21 December and 10 of the 12 warmest years in the 350-year daily temperature series occurred in the last 20 years (Ray *et al*., 2010). The thermal growing season for this region of the UK is now longer than at any time since the start of the daily temperature series in 1772 (DECC, 2010). Other signs include:

- In southern England oak leaves are sprouting 26 days before they did in 1950.
- Wild cherries are now blossoming two weeks earlier than in the 1970s.
- Rowan, box and cow parsley are all flowering 9 to 15 days earlier than they did 20 years ago.
- Sycamore is responding fastest to climate change through earlier bud burst compared with other large trees. Hawthorn and hornbeam are also coming into leaf earlier.

Therefore, an analysis of utility space degredation by trees and vegetation in relation to climate change is essential if proactive tree clearance programmes are to be planned and implemented with any degree of reliability.

## Materials and methods

Over 1700 experimental sites were established across the country covering the participating licence areas and the National Grid network in representative bioclimatic zones. At each site trees under and adjacent the OHPLs were cut and over the succeeding years measurements were taken to determine the annual re-growth rates and the rate at which the utility space was degraded by tree growth. This parameter is called utility space degradation (USD). This is an important concept because it integrates tree species, tree shape, soils, land use, location, etc. along the overhead spans. It differs from average growth rates in that it focuses on the key aspect, which is the fastest growing vegetation relative to the infrastructure.

The baseline measurements taken during this investigation were then analysed to see if there was any significant variation due to the land use at the locations, or to exposure, shading or regional location. The measurements were also interpolated, using bioclimatic zones, to give a continuous dataset of USD across the UK based on the meteorological conditions observed during the experimental period. This dataset was then used in conjunction with climate forecast data from UKCIP (Murphy *et al*., 2009) to project the likely impact of the high and low climate impact projections of UKCIP on the magnitude and spatial distribution of USD at 2020 and 2050.

## Results and discussion

The results indicate that there is no significant variation in USD in relation to the land use where the trees are located, (i.e. arable, forested, grassland, roadside, sparse woodland or urban). Nor were there significant differences in USD in relation to exposure or shading. However, significant differences were observed in relation to company, (i.e. regional differences) as shown in Figure 3.

Comparison of the USD between the individual genera/species of tree produced some interesting results, (see Figure 4). The error ranges recorded on lime (*Tilia* spp.), larch (*Larix* spp.),

Figure 3 Regional differences in USD as indicated by company location.

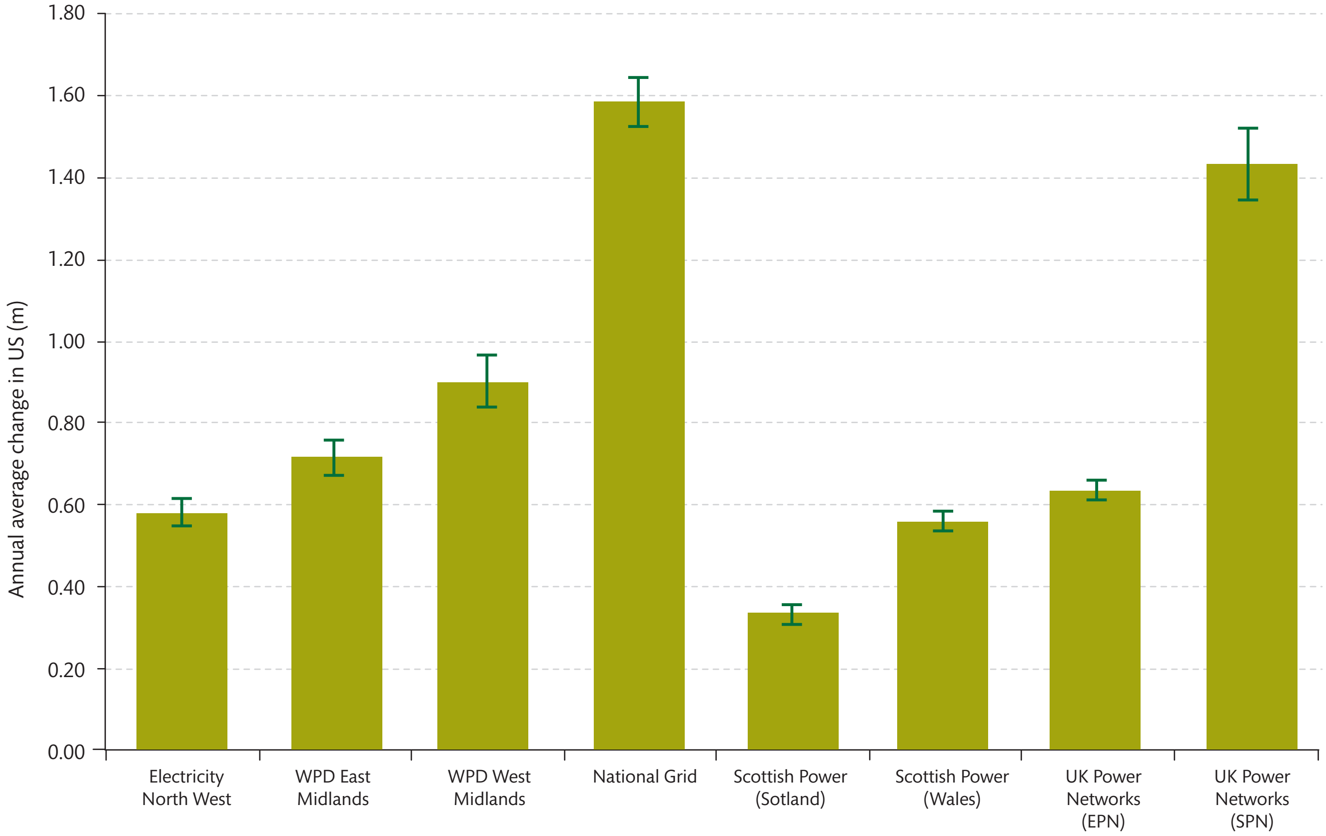
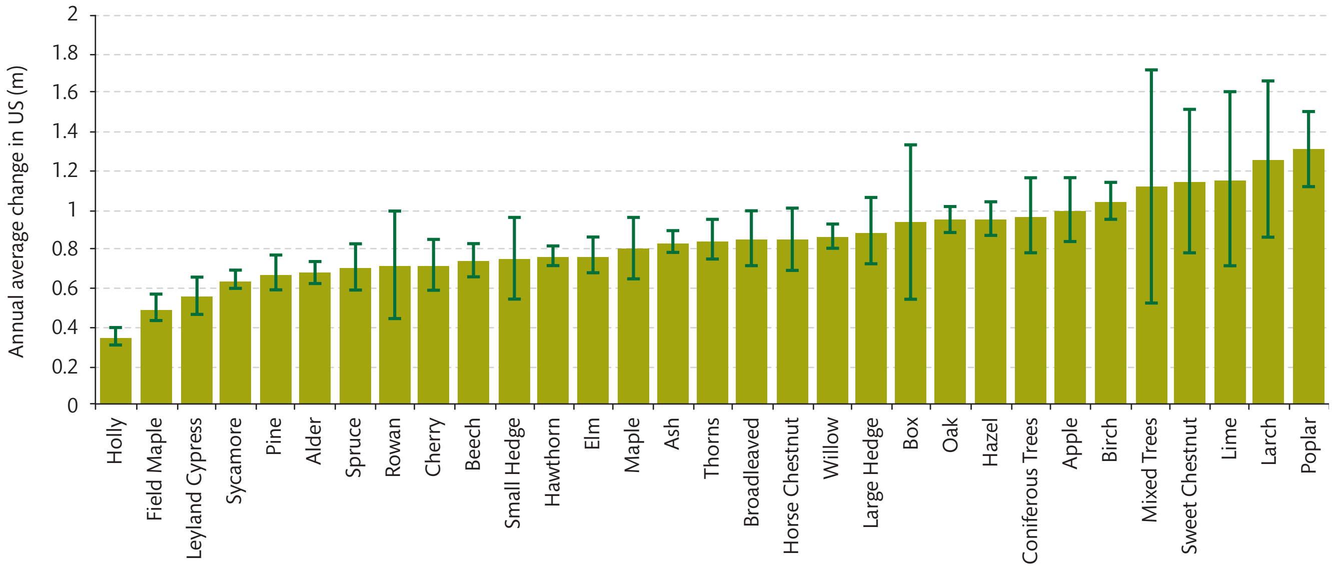



Figure 4 National average variation in USD by vegetation type.




Figures 3 and 4 and Table 2 are reproduced courtesy of ADAS

sweet chestnut (*Castanea sativa*) rowan (*Sorbus* spp.) and box (*Buxus sempervirens*) are very large, suggesting perhaps that the shape of the tree and its position relative to the conductors may be a key factor.

When comparisons are made with the climate change projections it can be seen that the changes from baseline measurements taken between 2008 and 2010 are projected to be between 16% and 30% higher in 2020 in the UKCIP 2020 low projection, and between 16% and 40% in the 2020 high scenario (Table 2). There is a spatial variation in growth rates and an obvious climatic variation between the different company locations. It seems that there are likely to be substantial changes in growth and variation over the next 10

Table 2 USD comparisons between the spatially averaged baseline readings and the 2020 low and 2020 high climate projections.

| Company | USD (m) | | | % Change | |
|---|---|---|---|---|---|
| | Baseline | 2020 Low | 2020 High | Baseline to 2020 low | Baseline to 2020 high |
| National Grid | 0.88 | 1.12 | 1.10 | 27 | 25 |
| UK Power Networks (SPN) | 1.08 | 1.38 | 1.29 | 28 | 19 |
| UK Power Networks (EPN) | 0.90 | 1.07 | 1.26 | 19 | 40 |
| Electricity North West | 0.67 | 0.83 | 0.78 | 24 | 16 |
| WPD East Midlands | 0.86 | 1.00 | 1.09 | 16 | 27 |
| WPD West Midlands | 0.90 | 1.10 | 1.07 | 22 | 18 |
| Scottish Power (Wales) | 0.78 | 1.00 | 0.94 | 28 | 21 |
| Scottish Power (Scotland) | 0.53 | 0.69 | 0.65 | 30 | 23 |

years with the UKCIP high end projections suggesting maximum variation in USD rates occurring in 2020. If the changes are more severe than are currently being projected, there may be some limitations to growth rates due to a reduction in rainfall and concomitant reduction in the availability of water.

## Implications

The implications of the projected climate change impacts are significant, not just for the utility sector in planning their proactive tree clearance cycles based on growth rates but also for the amenity/urban forestry sectors where tree pruning activities constitute a significant part of core business. Local authorities and private landowners alike will have to consider adjusting their maintenance regimes in line with the projected increasing growth rates, and also consider more carefully the selection of tree species for new and replacement planting schemes and select species that are resilient and suited to current conditions and to the changing climate in the 21st century and beyond.

# Controlling tree growth

## Background

As can be seen, trees are currently growing faster than had been anticipated and it is projected that the rates of re-growth will increase over the next 10 years. The projected changes in tree growth rates will have an impact upon the tree clearance cycles within the DNOs and the result is likely to be shorter cutting cycles and an increased emphasis on tree removal rather than pruning.

The projected increased growth rates notwithstanding, a major problem for most DNOs in the UK is that of pruning high value amenity trees and restricted cuts on the LV network. The former is where trees are located in prominent locations such as rural villages and village greens, conservation areas or prominent street trees where the overhead LV network is close to or through the crowns (see Figure 5). There is understandable public resistance to pruning these trees.

Figure 5 Typical bare wire overhead low voltage conductors with high value amenity trees adjacent to the conductors.


Restricted cuts occur when a landowner refuses consent for the full amount of cutting necessary to provide the required clearances that would last for the duration of the cutting cycle (four or five years), but allows the minimum amount of cutting to keep the lines clear of the conductors at that point in time. This means that the DNO has to return to the site every year at worst or every other year at best to re-prune the tree(s) to maintain the clearance distances and to comply with ESQC (A) R 2006. Most of the trees concerned are garden trees to which the owners are understandably attached.

Restricted cuts are a major drain on the DNO's resources, as it must send a cutting team back to the property every year or every other year and such visits typically cost three to five times as much as the cost of keeping the same team busy day to day on the regular clearance work. In addition, it can be very disruptive to the landowner, although it could be argued that s/he has brought the disruption upon themselves. However, if the rates at which the pruned trees re-grow could be slowed down without harming the trees, this would reduce the number of repeat visits and minimise disruption for the landowner.

## Tree growth regulators

Research has shown that compounds known as tree growth regulators (TGRs) can slow the growth rates of trees for three to five years depending upon species and are effective in extending pruning cycles in utility tree cutting (Burch and Wells, 1995; Chaney, 2002; Hotchkiss, 2003; Moore, 1998). The most effective compound of the TGRs available currently is paclobutrazol (PBZ) and previous research has shown that PBZ significantly reduced the growth rates of *Fraxinus excelsior* (ash), *Tilia x europea* (lime), *Acer pseudoplatanus* (sycamore) and *Cupressocyparis leylandii* (leyland cypress) in the UK (Hotchkiss, 2003).

PBZ is licensed in the UK for use on apple, pear, plum and cherry and for some nursery container stock, but not for use on amenity trees. PBZ has been shown to have beneficial effects on treated trees, that is it increases drought tolerance and the production of fine roots, and it has fungicidal properties that can combat vascular wilt diseases and tar spot on sycamore for example (Chaney, 2002; Hotchkiss, 2003).

A project to assess the efficacy of PBZ on amenity trees that impact overhead power lines in the UK was initiated in 2009, with four DNOs representing 10 licence areas participating (i.e. WPD including what was formerly CN, CE Electric (CE-E), Scottish & Southern Energy (SSE) and UKPN). As with the Climate Change Growth Study, this research is funded through the IFI Scheme. The research is led by the Bartlett Tree Research Laboratory at Reading University with assistance from ADAS. The aim of the project is to determine if PBZ is effective in slowing the post-pruning growth of the fastest growing tree species in the UK. If it is shown to be effective, the aim is to apply for a licence from the Chemicals Regulation Directorate (CRD) for its use on amenity trees.

## Materials and methods

Six field trial sites were selected located throughout the UK representing a diverse range of bio-climatic zones with at least one research site covering each of the participating network operators' licence areas (i.e. Boxworth in Cambridgeshire, Drayton in Warwickshire, Hull in Humberside, Myerscough in Lancashire, Raglan in Monmouthshire and Reading in Berkshire). The tree species selected for PBZ evaluation represented those that occur commonly on or near overhead networks (i.e. alder, ash, birch, leyland cypress, lime, poplar, hawthorn, sycamore and willow). Trees selected for project purposes were tagged and measured (diameter at breast height, dbh, 1.4 m).

The PBZ dosage for each tree was calculated and details provided to the contractor responsible for application of PBZ. Trees were treated in July and August 2009, under an experimental licence from the CRD. This was followed by a 15% top and side pruning of both treated and untreated trees.

PBZ was applied using a Rainbow Treecare Soil Injection System™ (see Figure 6) based on 1 x 1 metre spacing to a circular area the radius of which is three times the trunk diameter. A maximum of 250 ml of TGR plus dilutant was injected per point to a depth of 20–25 cm at a pressure of 30 psi (13.6 kg-f). This was split into a minimum of four equal applications around the base of the tree. The only exception to this was where the application was significantly less than 250 ml; in this case the injections were reduced to three. The quantity of PBZ injected was based on manufacturers' recommended rates as determined by tree species and diameter at breast height (Rainbow Treecare, 2007).

**Figure 6** Paclobutrazol applied using the Rainbow Treecare Soil Injection System™.

At each field site 30 trees per species were used: 15 PBZ treated and 15 water treated controls in three replicates of five pairs of trees. This experimental design was adopted in line with Official Recognition of Efficacy Testing Organisations (ORETO) guidelines for efficacy testing as below and analysed as a three randomised complete block design (Table 3).

**Table 3** Three randomised block design of PBZ experiment.

| PBZ (T1) | Control | PBZ (T1) | Control | PBZ (T1) | Control |
|---|---|---|---|---|---|
| T1 | C | T1 | C | T1 | C |
| T1 | C | T1 | C | T1 | C |
| T1 | C | T1 | C | T1 | C |
| T1 | C | T1 | C | T1 | C |
| T1 | C | T1 | C | T1 | C |

During the 2009 and 2010 growing season (July–August) a number of tree vitality measurements were recorded on PBZ treated and non-treated trees. These included chlorophyll fluorescence, chlorophyll measurement and leaf electrolyte leakage, all of which are reliable indicators of vitality (Percival, 2004, 2005). In addition, measurements were taken of the girth of the trees at dbh (1.4 m above ground). In 2010 the girths of the trees were measured again as was the extension growth of the test and control trees. Root cores were taken from all the trees pre and post treatment to measure the density of fine roots, pre and post application.

## Results and conclusions

In the first year (2009) there was no significant influence ($P<0.001$) of PBZ application on tree vitality at any of the field sites. Lack of statistical significance between PBZ treated and control trees during the first few months after PBZ application indicated no phytotoxic response during the first growing season. In the second year (2010) no long-term phytotoxic effects induced by PBZ application were recorded any tree irrespective of planting site and species (Percival *et al*., 2010).

A significant influence of PBZ on vitality and growth was recorded in 2010 (i.e. one year after PBZ application). Analysis of individual tree species (PBZ treated vs. non-PBZ treated control) at each field site shows that the influence of PBZ was manifest by:

- reduced shoot growth and trunk diameter;
- increased root growth;
- increased leaf photosynthetic activity (i.e. higher chlorophyll fluorescence);
- greener leaves (higher SPAD readings as a measure of leaf chlorophyll content);
- reduced electrolyte leakage (higher plant cell wall strength).

The effects of PBZ on growth varied between tree species. For example, reduction in stem extension in English oak and beech ranged from 39% to 75% and 13% to 42% ($P<0.05$) respectively, while effects on stem extension of poplar and willow ranged from 3% to 24% and 11% to 32% (not significant) respectively. However, conclusions are based on one growing season and should be interpreted with care.

Increased tree vitality recorded in PBZ treated trees over non-PBZ treated trees in 2010 indicates only beneficial effects caused by PBZ application (Percival *et al*., 2011).

## Implications for the utility and amenity sectors

While it is risky to place reliance upon on one year's data, the indications are that PBZ is effective in reducing extension growth in the test trees. The results thus far support the findings of Hotchkiss (2003) on ash, lime, sycamore and leyland cypress in the northwest of England. Therefore, the indications are that PBZ can be effective in the electric utility sector to slow tree re-growth rates in the situations in which it is intended to be used, that is on high value amenity trees and locations where landowners will only allow restricted cuts.

The implications for the amenity sector are also positive as local authorities could use PBZ to extend the time intervals between pruning regimes of street and other publicly owned trees.

The positive effects of PBZ on tree vitality are good side effects to the application of PBZ. It has been shown that positive responses of root growth to PBZ are often associated with increases in fine root production or increased branching (Chaney, 2002; Blaedow, 2003; Watson, 2006). For example soil injection of PBZ around declining mature oak trees increased fine root development 60% to 80% within 20 cm of the base of the tree (Watson 1996). The results of the present study show similar responses with increased root dry weight recorded in most trees treated with PBZ. In the USA PBZ is regularly applied to trees where underground utilities have been installed through trenching to encourage increased production of fine roots (Chaney, 2003.). This is an area that could be further investigated in Britain.

Another aspect to the increased production of fine roots, some of which in time will develop into woody roots, is that perhaps this could result in increased stability in treated trees. However, this is an area that requires further research.

## Research on trees and resilience

Since 31 January 2009 all DNOs are required to operate a progressive tree cutting and felling programme in accordance with industry standard ENA ETR 132 (ENA, 2005), which outlines a risk-based methodology for targeting strategic overhead line routes to improve network performance in abnormal weather conditions. Trees that are within falling distance of the overhead lines must be assessed to ascertain the likelihood of failure of the whole tree or parts of the tree, which in the event of failure in abnormal adverse weather conditions would cause service interruptions and/or damage to the infrastructure. In reality this means that any trees that are within falling distance of OHPLs are 'resilience trees' and must be assessed and managed to prevent them causing interruptions and/or damage in abnormal weather conditions.

The problem is that it is not the defective, dead, dying or dangerous trees that cause DNOs problems because these are identified as part of routine clearance work and managed appropriately. Nor are the trees that a competent and experienced tree assessor would recognise as possibly problematic and decide to investigate further to assess whether not they pose a danger, as these are identified, assessed and managed appropriately.

Trees that seem 'healthy' and not a cause for concern pose the most serious threat. Post-mortem analysis of six major storm events across the USA revealed that between 55% and 70% of the trees that failed and caused damage to the OHPLs and associated apparatus had no discernable defects and would have been regarded as 'safe' had they been assessed prior to the storm events (Guggenmoos, 2009). This finding has significant implications for understanding and mitigating tree-related damage and outages in major storm events. The degree to which the OHPLs are exposed to trees (i.e. the number of trees per kilometre edge) is the best measure of exposure, and in the USA this significantly correlates with the frequency of tree-caused outages, with a correlation coefficient of between 0.85 and 0.92 (Guggenmoos, 2009).

It was decided to investigate whether or not it is possible to devise an objective assessment system that would facilitate reasonable predications of the likelihood of such trees to fail in abnormal weather conditions. Central Networks (now WPD) is funding a two-year MPhil study based at Myerscough College, Preston, Lancashire, and in cooperation with Reading University, to see if such a predictive system can be devised. The project started in November 2010 and is due for completion in 2012. The project will investigate areas such as existing peer-reviewed tree assessment systems; risk assessment methods from other industries; the relevance of the International Tree Failure Database and California Tree Failure Database to assess the probability of failure of trees in the UK; Meteorological Office wind forecasting models; tree failure profiles; tree growth characteristics; etc.

It is hoped that the research will devise a system of predicting the failure potential of trees in abnormal weather conditions that is objective and based on measurable parameters, which are valid, robust, replicable, mathematically sound and easily applied.

If such a system can be devised, its use would extend far beyond the utility sector, where it would greatly assist DNOs to discharge the resilience obligation. For example the system could be used by local authorities to ascribe a probability of tree failure in extreme adverse weather conditions, which would assist in planning maintenance programmes and allocation of resources to deal with the most risky trees.

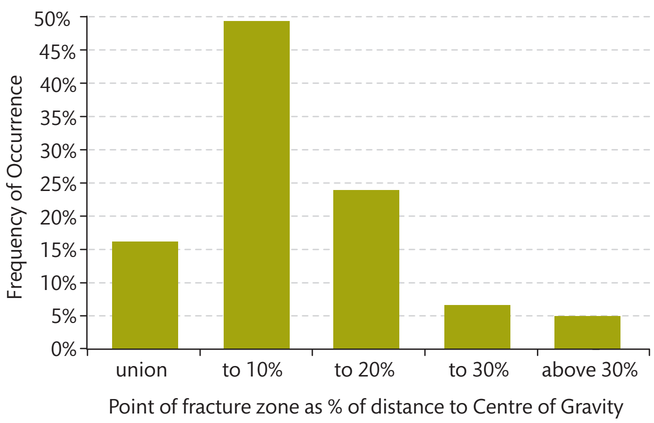
## Branch failure research

Tree-caused outages are a major problem for DNOs. Traditionally the focus of utility vegetation managers has been on individual trees that have characteristics that would predispose them to failure. However, the failure of small- to medium-sized branches within the crowns of trees in proximity to or overhanging energised electricity conductors is also a consideration that has not been given as much attention as whole tree failure. Like whole tree failure, the failure of individual branches can cause mechanical damage to the infrastructure. Also branches can provide a fault pathway between phases which can result in an electric mode of failure.

In 2008 an investigation into the modes of failure of small- to medium-sized branches in the crowns of trees was initiated in the USA. It was funded by the ISA Tree Fund and National Grid (USA). The investigation included a literature review; interpretation of photographs of tree-caused outages; a survey of the industry's experience; and destructive testing of branches of six species of tree (Goodfellow, 2009).

The small- to medium-sized branches included in the experiments ranged between 2 cm and 8 cm in diameter and individual branches were mechanically loaded to the point of destruction. The research identified a critical zone of failure within 10% to 20% of the branch length to the union (Figure 7). The majority of branches tested (48%) failed at a point that was 10% of branch length from the union, and 24% failed 20% from the union. Very few branches (15%) failed at the union, which conflicts with common perceptions. The study also found that a relatively small reduction in branch length resulted in substantial reduction in load-induced stress in branches, and this may be an effective means of mitigating the risk posed by branches adjacent to, but particularly overhanging, conductors (Goodfellow, 2009).

**Figure 7** The points of failure of mechanically loaded branches.

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More research is needed on this aspect to understand the effect that the reductions in branch length might have on the natural resonance of the tree, i.e. to study the dynamic effects of such reductions using the methodology developed by James (2010).

## Summary and the future

The utility arboriculture sector in the UK has taken the initiative and invested in research that is environmentally sound and should lead to significant savings, efficiencies and more reliable networks. This is being done because the need has been identified and there is significant statutory pressure on the electric utilities to manage trees and vegetation effectively.

The principal driver in tree and vegetation management is the growth rates of the most commonly occurring trees on or adjacent to the OHPLs. Growth rate dictates the cutting cycles and indirectly the cost of managing those cycles (the shorter the cycle the higher the cost). Research set out above confirms regional differences in tree growth rates and that rates of growth are likely to increase significantly in the next ten years.

The possible use of the TGR paclobutrazol to slow re-growth rates is being investigated. If this proves to be effective it will provide a cost-effective way of bringing fast-growing trees into the clearance cycles and buy time to allow the DNOs to plan and implement diverting or undergrounding some of the OHPL network, specifically the LV network. It is also intended to apply for a licence from the CRD to use PBZ on amenity trees, so that its benefits can be realised in the local authority and private tree care sectors, as well as within the utility sector.

Trees that could damage the OHPLs and cause supply interruptions in abnormal weather conditions pose a particular problem to the DNOs. Most of the trees that fail and cause damage and supply interruptions are typically healthy specimens within falling distance of the OHPLs. Therefore, research has been initiated to investigate whether or not a system can be devised to assess these trees and predict the likelihood of them failing in extreme adverse weather conditions. This research is due to report towards the end of 2013.

Innovative research in the USA into the failure of small- to medium-sized branches within the crowns of trees has revealed that the critical failure point is not at the branch union but at a distance from the union equivalent to 20% of the length of the branch. It also revealed that relatively small reductions in branch length result in significant reductions in load-induced stress.

Although all the research described in this paper is principally aimed at the electrical utility sector to assist it to become more efficient and deliver safer networks, the implications go beyond that sector. The research has significant benefits to the amenity and urban forestry sectors as well.

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## References

BLAEDOW, R.A. (2003). *The Fungicidal Properties Associated with Paclobutrazol*. MSc Thesis, Purdue University, Indianapolis, Indiana, USA.

BURCH, P.L. AND WELLS, R.H. (1995). Tree growth evaluated 10 years after application of Paclobutrazol tree growth regulator. *Down To Earth* **50**(2), 5pp.

CENTRAL NETWORKS (2011). *Tree Management Specification*, Final, February, 48 pp.

CHANEY, W.R. (2002). Tree growth retardants provide multiple benefits. *Wisconsin Arborist* **21**(5), 1–2.

CHANEY, W.R. (2003). Tree growth retardants: arborists discovering new uses for an old tool. *Tree Care Industry* **54**, 2–6.

DEPARTMENT FOR ENERGY AND CLIMATE CHANGE (2010). *Thermal Growing Season 1772–2009*. [Online] Available at: http://www.decc.gov.uk/assets/decc/statistics/climate_change/1_20100319151841_e_@@_thermalgrowingseasonsummary.pdf

DEPARTMENT OF TRADE AND INDUSTRY (2006). *Full Regulatory Impact Assessment: The Electricity Safety, Quality and Continuity (Amendment) Regulations 2006*. Engineering Inspectorate DTI June 2006 URN 06/1295, 59 pp.

ELECTRICITY SAFETY, QUALITY AND CONTINUITY REGULATIONS (2002). Statutory Instrument 2002/2665.

ELECTRICITY SAFETY, QUALITY AND CONTINUITY (AMENDMENT) REGULATIONS (2006). Statutory Instrument 2006/1521.

ENERGY NETWORKS ASSOCIATION (2004). *Overhead Line Clearances*, Technical Specification 43–8. ENA Publications, London.

ENERGY NETWORKS ASSOCIATION (2005). *Vegetation management near electric overhead lines for the purpose of improving network performance under abnormal weather conditions.* Engineering Technical Recommendation 132, ENA Publications, London.

ENVIRONMENTAL CONSULTANTS INC (2009). *E.ON: Central Networks LV/HV/EHV Vegetation Management Programme* – Final Report May 2009.

GOODFELLOW, J. (2009). *Development of risk assessment criteria for branch failures within the crowns of trees*. Final Report of BioCompliance Consulting Inc. 78 pp.

GUGGENMOOS, S. (2009). Managing tree-caused electric service interruptions. *UAA Quarterly, Special Edition*, 4–9.

HOTCHKISS, D. (2003). *A Study of the effects of Paclobutrazol on the growth rate of fast growing tree species in the United Kingdom and Ireland*. MSc Thesis, University of Central Lancashire, Preston, England.

JAMES, K.R. (2010). *A dynamic structural analysis of trees subject to wind loading*. PhD Thesis, University of Melbourne, School of Land and Environments, Melbourne, Australia. [Online] Available at: http://dtl.unimelb.edu.au

JOHNS, H.R. AND HOLEWINSKI, D.E. (1981). How to develop or improve your line clearing program. *Journal of Arboriculture* **7**(12), 329–332.

MOORE, G.M. (1998). Tree growth regulators: issues of control, matters of management. *Journal of Arboriculture* **24**(1), 10–18.

MURPHY, J.M., SEXTON, D.M.H., JENKINS, G.J., BOOTH, B.B.B., BROWN, C.C., CLARK, R.T., COLLINS, M., HARRIS, G.R., KENDON, E.J., BETTS, R.A., BROWN, S.J., HUMPHREY, K.A., MCCARTHY, M.P., MCDONALD, R.E., STEPHENS, A., WALLACE, C., WARREN, R., WILBY, R. AND WOOD, R.A. (2009). *UK Climate Projections Science Report*. Met Office, Hadley, Exeter.

PERCIVAL, G.C. (2004). Evaluation of physiological tests as predictors of young tree establishment and growth. *Journal of Arboriculture* **30**(2), 80–92.

PERCIVAL, G.C. (2005). The use of chlorophyll fluorescence to identify chemical and environmental stress in leaf tissue of three oak species. *Journal of Arboriculture* **31**(6), 10–23.

PERCIVAL, G.C., NOVISS, K., ABBATT, J. AND WALKINGTON, M. (2010). *The Effects of Tree Growth Regulators (TGRs) on Fast Growing Trees and Application to Utility Arboriculture*. First Progress Report to IFI Partners (unpublished).

PERCIVAL, G.C., NOVISS, K., ABBATT, J. AND WALKINGTON, M. (2011). *The Effects of Tree Growth Regulators (TGRs) on Fast Growing Trees and Application to Utility Arboriculture*. Second Progress Report to IFI Partners (unpublished).

RAINBOW TREECARE (2007). *Cambistat Application Guide*. Rainbow Treecare Scientific Advancements, 8 pp. [Online] Available at: http://www.cambistat.com

RAY, D., MORISON, J. AND BROADMEADOW, M. (2010). *Climate Change: Impacts and adaptation in England's woodlands*. Forestry Commission Research Note (FCRN201). The Forestry Commission, Edinburgh.

WATSON, G. (1996). Tree root system enhancement with Paclobutrazol. *Journal of Arboriculture* **22**(5), 211–217.

WATSON, G.W. (2006). The effect of Paclobutrazol treatment on starch content, mycorrhizal colonisation and fine root density of White oaks (*Quercus alba*). *Arboriculture and Urban Forestry* **32**(3), 113–117.

# Challenges and problems of urban forest development in Addis Ababa, Ethiopia


## Abstract

A study was carried out in Addis Ababa, the capital city of Ethiopia. Urban forests in Addis Ababa are affected by various problems such as encroachment, illegal cuttings, low legal enforcement and improper tree selection. Consequently, the main objective of this study was to assess the challenges and problems of the city's urban forests and to provide recommendations for different stakeholders who manage and participate in rehabilitating them. To achieve this, primary and secondary data were collected from government organisations who engage in the planting and care of urban trees. Results show the rate of illegal human intrusion doubled in two forest areas between the years 1997 and 2008. Of seedlings planted along the major road of the city, 87% were exotic species with their proportions ranging between 60 and 84%. The diversity of tree species along streets was very low (i.e. about 0.40%). Between 25 and 100% similarities of tree species were found among differing street locations. Among the exotic tree species recorded *Grevillea robusta*, *Acacia melanoxylon* and *Jacaranda mimosifolia* were found in the greatest proportions. The density of exotic tree species in three public parks was higher than indigenous trees by 74.7, 66.9 and 72.1% respectively. New tree plantings were decreasing at a household level showing a 'J' shape curve (low proportion of trees at lower age classes and high proportion of trees at higher age classes). To maintain tree coverage increased lower age class trees need to be planted. Proper guidelines to develop and manage the urban forest need to be formulated. This will help to provide green coverage according to the master plan of the city which can last for a prolonged period without creating conflict between stakeholders.


## Introduction

Urban forestry refers to any revegetation effort including the planting of trees and shrubs whose design is intended to improve the environmental quality, economic opportunity, or aesthetic value associated with a city's landscape. The perception that comes to mind regarding urban forest is street trees and ornamental woody plants. However, the urban forest is a complex system of trees and smaller plants, wildlife, associated organisms, soil, water and air quality in and around a city.

Urban afforestation efforts are particularly necessary because of the quality of the environment in urban landscapes. The urban environment is characterised by air and water pollution, settlement in fragile ecosystems, and loss of water catchments and floodplain surface areas.

In Addis Ababa *Eucalyptus* species have been introduced since 1895 to satisfy the growing demand for wood and construction material and to reduce the pressure on the remaining natural vegetation. Without the successful introduction of *Eucalyptus* species under the reign of Emperor Menelik II, it is unlikely that Addis Ababa would have become the capital of Ethiopia and diplomatic centre of Africa (Hancock, 1995).

However, in recent years the urban forest of Addis Ababa including the upper catchments of the Entoto Mountain forest area has been dwindling at an alarming rate. This study aimed to assess the problems and challenges facing the urban forests of Addis Ababa and to recommend solutions based on results of the assessment.


**Keywords:**

indigenous trees, tree removal, urban forest management



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# Problem statement

Addis Ababa, the capital and the most populated city of Ethiopia with a population of 2 112 737 million (CSA, 1999), grew at a rate of 2.1% from 1994 to 2007. A rapid and unplanned expansion and commercial development, along with population pressure, has meant the city environment is deteriorating with time. At present the forests of Addis Ababa are almost transformed to urban habitats accommodating a excessive population due to a high rate of rural–urban migration. In addition, industrialization within the urban areas and conversion of different land use within the city and the surrounding urban areas has caused the rapid depletion of existing tree cover during the past 100 years. This depletion of green resources has indicated that succeeding city governments had no proper long-term plans to keep the city green with the exception of intervening in some areas such as the establishment of a few parks and roadside plantations under a city beautification programme. These interventions also have diverse problems for sustainable management of the urban forest. Residents in general are not aware of the importance of existing tree cover in and around their living premises.

With the rapid expansion of the city, wide roads replaced narrow and unpaved roads, leaving a host of disturbed areas. However, there are no plans to plant new trees along these roads and fill the space created by different development activities. No serious effort has been made to reclaim land in a well-planned manner to allow the city to have adequate space along with its growth. On the contrary, an alarming scenario observed is the reduction in open spaces over time. To ameliorate the existing conditions, there is an urgent need to identify and assess the main problems and challenges of urban forests within Addis Ababa in order to formulate a sustainable plan and strategy of urban forest development and management.

# Objectives

- To assess the major drivers of urban forest challenges and the problems urban forests face within Addis Ababa.
- To recommend solutions for the sustainable planning of urban forest development.

# Materials and methods

## Location

Addis Ababa is located in the central highlands of Ethopia. Geographically, it is located at 9° 38′ 0″N between 38° 42′ 0″E, with the lowest elevation of 2326 m above sea level at Bole International Airport, in the southern periphery, and the highest over 3000 m at Entoto Mountains, north of the city.

## Climate

The average maximum temperature ranges between 17 and 22°C and the average minimum temperature varies between 11 and 14°C. The average rainfall is *c.* 1200 mm per year, with the major rain season occurring between June and September.

## Land use

The city administration covers an area of 54 000 ha. The city has a recently revised master plan which allocates a total 22 000 ha (about 41% of the city) for greenery. The forest land, agricultural land, woodland, parks and riverbanks are considered as the major green components of the city. The peri-urban forest area occupies 8528 ha.

## Site selection for data collection

The selected sites for urban forest data collection were:

- For roadside tree plantations: CMC to Legehar, Legehar to Piazza, Piazza to the Semen Hotel, Sidis Kilo to Meskel Flower, Meskel Flower to Bole, Kasanchis to the Ethiopia Hotel, National Bank to Goma Kuteba, Megenagan to Signal, Salitemehret to Gerji, Goma Kuteba to Tekelehaimanot and Tekelehaimanot to Piazza.
- For the assessment of trees planted in residential areas, real estate and newly established residential areas around CMC, Gerji, Lebu, Lafto and Asko were visited.
- Assessments on four selected functional parks (Beherstige, Gola, Sheger and Yeka parks) were made.
- For data on river banks Kebena, bambis and tributaries for the major river of the city were assessed.
- To assess trees planted in church compounds six churches were selected by their tree coverage (Silase, Saint George (Pissa), Saint Merry, Peteros paulos, Bole Medhanialem and Kechene Medehanialem).
- For the assessment of roadside tree plantations 11 roads were selected based on their age, length and location.
- A survey was also made on peri-urban mixed and pure plantation forest areas of the city.

## Data collection methods

Data was collected on peri-urban forest area, selected parks, roadside plantation through transect walk. Questionnaires were developed to collect data from all sub-cities to assess problems in relation to trees planted in different institutional private and other compounds within the city.

# Analysis

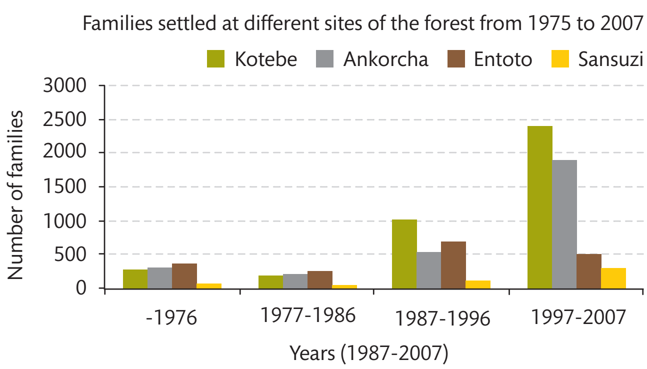
Descriptive statistics (such as percentage, pie-chart, histogram) were used to analyse and present the data. SYN–TAX 2000 soft ware was used to determine the diversity and similarity of tree species in three parks and eight streets of the city. In addition photographs have been used to support discussions.

# Results and discussion

## Encroachments

From Figure 1 we can infer that the population pressure within the forest area is increasing at an alarming rate. The highest encroachment is observed in the Kotebe and Ankorcha forest areas. Figure 1 indicates that the rate of intrusion doubled in these two areas between the years 1997 and 2007.

Figure 1 Population pressure on upper catchment's forest area of Addis Ababa.

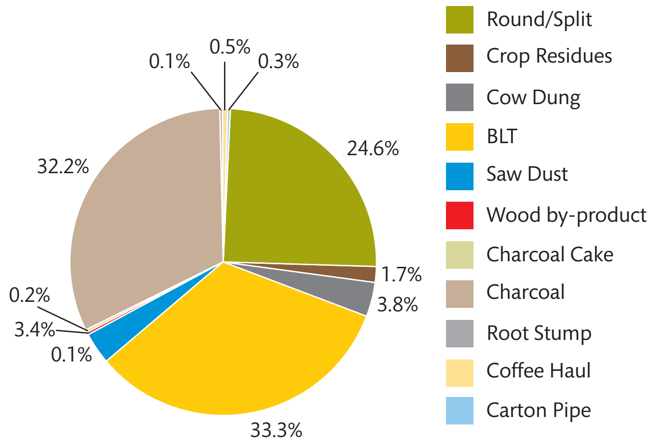



Thus, the forest in Yeka sub-city is in a progressive depletion and degradation state due to land use change of the forest area into housing settlement.

## Deforestation

In Addis Ababa tree branches, leaves, twigs (BLT) and charcoal provide the largest proportion of energy derived from biofuels, followed by round/split wood (24.6%; Figure 2). Remaining biofuels represent 10% of the total biofuel consumption.

Figure 2 Contributions to household energy consumption by biofuel in Addis Ababa.




About 10 500 women in Addis Ababa are currently engaged in fuel wood collection and selling from the forest area. Fuel wood selling was another major threat for forest depletion over the forest area of Addis Ababa.

On the other hand, socio-economic background assessment of the households involved in fuel wood sales indicate that they are living under the poverty line, and are incapable of sustaining their families with their low level of income. Consequently, poverty is another important cause of urban forest degradation. Moreover, besides fuel wood, construction materials such as posts, pole and pillars were also exploited and sold.

Between 2006 and 2007, 71 tree poachers were caught in the Kotebe (59%) and Ankorcha (41%) forest areas. All of the poachers were living within and around a forest area, were male and were between 18 and 35 years in age. Tree poachers use different soundless cutting equipments and the equipment is prepared in a form not to be identified by security personnel. Such conditions make it difficult for forest security personnel to protect the forest from poachers (Figure 3).

In addition to the settlers and fuel wood collectors, illegal tree cutters are also one of the major problems in the forest area environment contributing to the depletion of forest resources within Addis Ababa.

Figure 3 Partial view of equipment used by tree poachers in the upper catchment forest area.

## Street trees and associated problems

From six new roads surveyed almost all did not have space for pedestrian tree planting. In some of the newly constructed roads the agency responsible planted the trees badly, which impacted detrimentally on survival. This was due to poor soil structure, aeration and drainage problems caused by compaction. Roots of trees, shrubs and other plants cannot grow optimally in compacted soils. Furthermore, water does not drain well into and through compacted soil. Insufficient oxygen was available to plant roots in the compacted soil. Soil temperature also influenced root growth by reducing the rate of chemical and biological processes.

## Infrastructure development

In Addis Ababa most of the underground utility trenching work for telecommunication, sewers and water was not undertaken in a co-ordinated manner. Damage to tree roots occurred during the installation and maintenance of service utilities. Root damage from trenching is not unique to newly developed areas in Addis Ababa, and also occurred in more established communities as a result of maintenance, or installation of utilities, such as fibre-optic lines (Figures 4a–c).

The development of infrastructures such as water lines and tankers, new roads and repair and/or expansion of old roads affected trees found in each area to include household compounds (Table 1). Moreover, no one consulted the owner of the trees while trees were cut, in turn having a negative impact on the future development of the green area and initiating the community to participate in future tree planting.

Figures 4a–c Trenching as a result of telecommunication installation of fibre-optics.

Table 1 Number of trees cleared for infrastructure in the mountain forest area of the city.

| No. | Infrastructure reason for cutting of trees | Location | No of trees cleared | |
|---|---|---|---|---|
| | | | Indigenous | Exotic |
| 1 | Water line | Yeka | 0 | 27 |
| 2 | Water tanker area | Yeka (Ankorcha) | 0 | 131 |
| 3 | High tension electric power line | Yeka (Ankorcha) | 0 | 344 |

## Problems with selection of appropriate urban forest species

From the assessment made, it can be observed that most of the trees planted in Addis Ababa do not fulfil any specific selection criteria. For example, no evidence exists to show consideration for factors such as the purpose of the tree (shade, fruit, seasonal colour, windbreak), location of the planting site (overhead and/or below-ground wires, existing utilities), size of tree (i.e. space to accommodate large, medium or small size trees), and existing soil conditions (depth, fertility and structure). Due to the lack of these factors most of the trees planted within the city are facing several problems detrimental to their survival. As a result they do not provide the required environmental, social and economic functions they should. On the other hand, since selection criteria to date focus on flower colour and attractive morphology, they neglect other important characteristics such as a poisonous nature (e.g. *Nerium oleander*) and invasiveness of some species that impact detrimentally on socio-environmental problems and health.

In the survey undertaken it was identified that poisonous plant species such as *Nerium oleander* and *Lantana camara* were planted along roadsides, recreational parks and compounds within the city. Since popular culture is to use plant twigs for tooth brushes, the negative impact of such plants potentially can be high. In recreational parks children may cut and eat plant parts because of their attractive flowers. Consequently, the toxic chemical contained within the petals may affect their long-term health. In addition *Acacia melanoxylon* is one of the dominant species planted along streets and in the forest areas of the city. In 2008 from the total planted exotic tree species in the upper catchments of Addis Ababa 55 939 seedlings were *Acacia melanoxylon* and the survival rate of this species was 75.7%. Since this tree grows quickly and up to 45 m in height, this species can replace native non-tree vegetation, such as grass and shrub land (Geldenhuys, 1986).

Therefore, it is critical to note that maximum benefits are gained from planting the right trees in the right place. Many conflicts can be reduced or avoided by careful planning and by matching tree characteristics to site conditions. As indicated in Table 2 the major motive (72%) to seek permission to cut trees in all sub-cities by the community was to avoid the risk associated with mature trees. Consequently, considering size at maturity and form of the tree crown and root system are important characteristics when planting trees in and around compounds because of potential interference with utility lines, pavements, structures and signsposts.

Table 2 Ranked tree cutting reasons in the sub-cities of Addis Ababa.

| No. | Reasons for cutting of trees | 1st | 2nd | 3rd |
|---|---|---|---|---|
| 1 | Conflict between neighbourhood | 0% | 100% | 0% |
| 2 | To avoid risk caused by the trees | 72% | 0% | 28% |
| 3 | For economic reason/utilize | 28% | 0% | 78% |

According to the survey made in all the sub-cities of Addis Ababa the major problems created by urban trees are branch shed or whole tree failure damaging houses, buildings, cracking of concrete and interference with above-ground utilities respectively. As indicated in Table 3, all sub-cities rank leaves and branches (57%) as the first and roots (57%) as the second reasons given by individuals for requests to cut down trees planted within their compound.

Table 3 Plant organ ranked as reasons for tree felling request in the sub-cities of Addis Ababa.

| No. | Plant organ | Rank by sub-city | | | |
|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th |
| 1 | Leaves and branches | 57% | 14.3% | 28.5% | 0% |
| 2 | Root | 14.3% | 57% | 28.5% | 0% |
| 3 | Stem | 28.5% | 14.3% | 28.5% | 28.5% |
| 4 | Fruit | 0% | 14.3% | 14.3% | 71.4% |

Tree roots growing under asphalt or cement pavement can cause the pavement to heave. To alleviate such problems appropriate species selection together with site factors should be given prime consideration. According to Gilman (1997), the planting site should be located at least 3.6 m from a major underground utility line for large trees. *Grevillea robusta*, *Jacaranda mimosifolia*, *Cuperssus lusitanica*, *Casuarina equisetifolia* and *Acacia abyssinica* planted along roads within Addis Ababa can come into contact with electric wires. Tall-growing trees near overhead lines can cause service interruptions when trees reach a certain height. Appropriate selection and placement of trees in and around overhead utilities can eliminate potential public safety hazards, reduce expenses for utilities and improve the appearance of landscapes.

According to Gilman (1997), for sites which have above-ground utility lines then selection of small species that will 'top out' at least 1.5 m below the wire are important, or selection of a species with a narrow crown planted so that it will not grow into a utility line.

# Diversity of tree species within different green areas

## Diversity of tree species along major roads

The present study indicated that the proportion of indigenous tree species planted along streets is between 10 and 40% whereas the proportion of exotic tree species ranged between 60 and 84%. The contribution of urban forest in conserving indigenous trees of Ethiopia or adopting indigenous species for ornamentation is low (Table 4). Moreover, though the exotic tree species are contributing towards the green cover of the city, these species have not had sufficient time adaptation to the ecology of the city so face their own problems (e.g. *Cupressus lusitanica* affected by severe aphid infection).

Table 4 Tree species along five major streets in Addis Ababa.

| No. | Street | Tree species | | Proportion of indigenous tree as % |
|---|---|---|---|---|
| | | Exotic | Indigenous | |
| 1 | Megenanga to 22 | 18 | 3 | 14.3 |
| 2 | Legehar to Piazza | 13 | 3 | 18.8 |
| 3 | Piazza to Semen Hotel | 16 | 4 | 20.0 |
| 4 | Sidis Kilo to Meskel Square | 18 | 11 | 37.9 |
| 5 | Meskel Square to Bole | 13 | 4 | 23.5 |

As shown in Table 5 the diversity of tree species along the streets of Addis Ababa is 0.4064, indicating that the contribution of street trees towards diversity is very low and that most of the streets have similar tree species composition. This may impact on urban flora diversity and also if disease outbreak occurs in one street it will detrimentally affect all trees found in the other streets.

Table 5 Diversity of street trees in Addis Ababa.

| No. | Name | Mean | Stand.Dev. | Sum | D` |
|---|---|---|---|---|---|
| 1 | STREET1 | 3.333 | 8.165 | 20.0000 | 0.0000 |
| 2 | STREET2 | 7.000 | 8.944 | 42.0000 | 0.6066 |
| 3 | STREET3 | 43.000 | 67.510 | 258.0000 | 0.4910 |
| 4 | STREET4 | 2.667 | 6.532 | 16.0000 | 0.0000 |
| 5 | STREET5 | 7.000 | 14.297 | 42.0000 | 0.2540 |
| 6 | STREET6 | 5.000 | 6.000 | 30.0000 | 0.6333 |
| 7 | STREET7 | 14.333 | 21.454 | 86.0000 | 0.5222 |
| 8 | STREET8 | 3.500 | 2.811 | 21.0000 | 0.7438 |
| **Averages** | | **10.73** | **16.96** | **64.37** | **0.4064** |

D = Simpson`s diversity index for infinite population = 1 - sum (Pi*Pi), where Pi is the fraction of individuals belonging to the i-th species.

Six tree species were identified that densely covered the eight surveyed streets (Table 6). Diversity is important in any urban forest ensuring that entire urban canopies are not destroyed by problems such as aphid infestation which wiped-out *Cuppurssus lusitanica* in Addis Ababa when this species was overplanted as a hedge.

Table 6 Commonly planted tree species in eight streets located within Addis Ababa.

| No. | Species | Number of tree stems |
|---|---|---|
| 1 | *Acacia melanoxylon* | 97 |
| 2 | *Casuarina cunninghamiana* | 46 |
| 3 | *Grevillea robusta* | 263 |
| 4 | *Jacaranda mimosifloia* | 66 |
| 5 | *Phoenix reclinata* | 35 |
| 6 | *Spathodeia nilotica* | 8 |

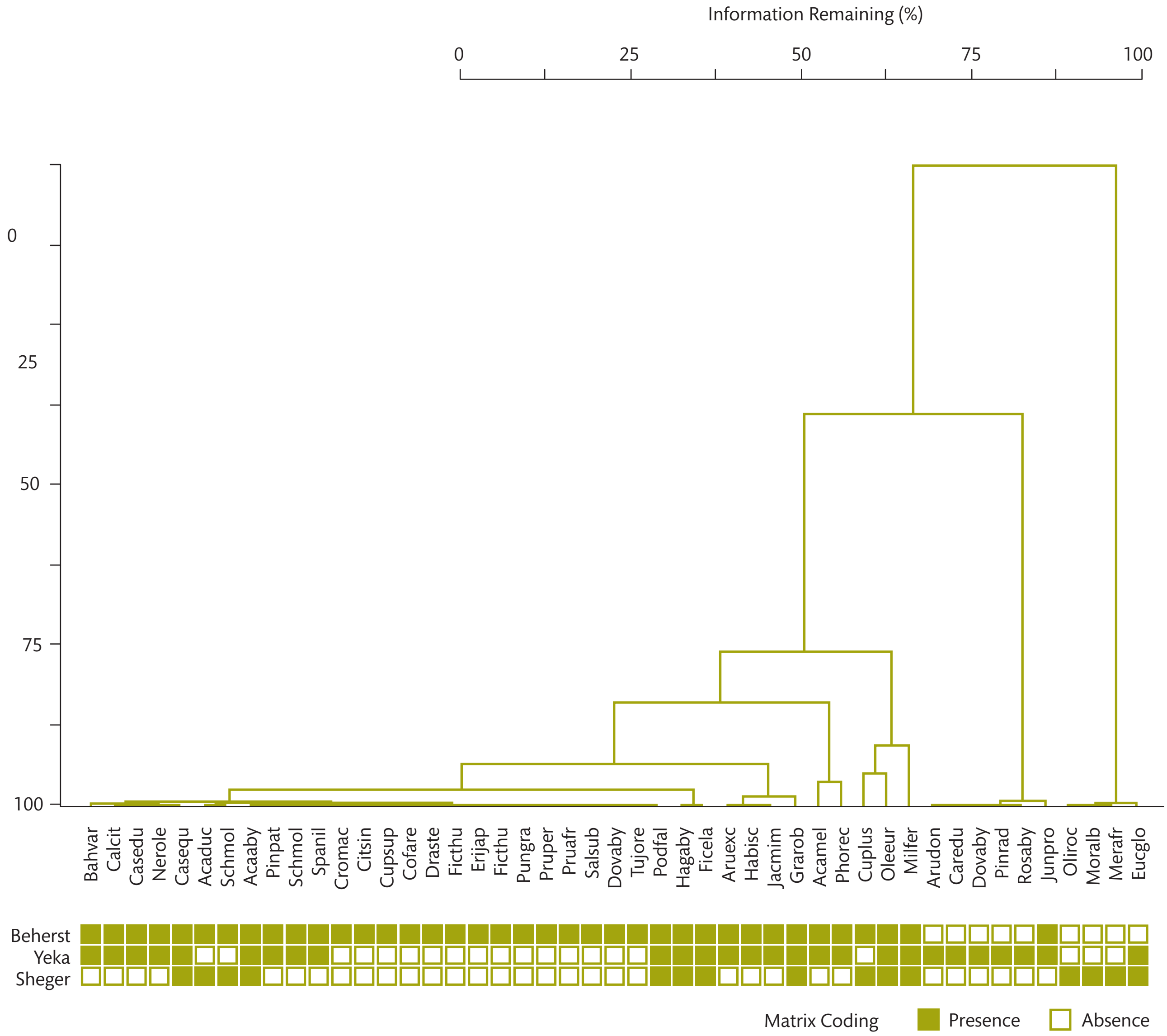
Out of the six tree species in Table 6, *Grevillea robusta*, *Jacaranda mimosifolia* and *Acacia melanoxylon* are distributed widely in the city. This limited diversity of species may have negative impacts on the survival of dominant species where outbreaks of disease and pest attack are recorded to which these trees are vulnerable.

## Diversity of species in three functional parks

Beherstige Park had a higher number of tree species than Yeka Park while Sheger Park has the lowest number of tree species (Figure 5).

Yeka Park had similar proportions of indigenous and exotic species. On the other hand the density of exotic tree species

Figure 5 Diversity of species in three functional parks (Beherstige,Yeka, Sheger).




in Yeka, Sheger and Beherstige was (74.7%), (66.7%) and (72.1%) respectively. This indicates that the density of exotic tree species is higher than the indigenous tree species in these parks (Table 7).

*Eucalyptus globulus* was found dominantly in the upper catchment's forest area of the city. *Juniperus procera* is a naturally grown indigenous tree species found growing next to *Eucalyptus globulus* in forest areas. As indicated in Table 8, 62.8% of forest cover was by exotic tree species. Cities such as Kuala Lumpur, Rio de Janeiro and Singapore (Chin and Corlett, 1986; El Lakany, 1999; Webb, 1999) still have tracts of tropical rainforest within their boundaries. These examples indicate that there should be a strong intervention by planting indigenous tree and reducing the number of exotic tree species to attain indigenous tree conservation zones.

Table 7 Type and density of exotic and indigenous tree species in four parks.

| No. | Park | Type of species | | No of individual trees (density) | | |
|---|---|---|---|---|---|---|
| | | Exotic | Indigenous | Exotic | Indigenous | % density of exotic |
| 1 | Gola | 8 | 9 | - | - | |
| 2 | Yeka | 12 | 12 | 635 | 215 | 74.7 |
| 3 | Sheger | 14 | 19 | 200 | 99 | 66.7 |
| 4 | Beherstige | 26 | 16 | 2800 | 1080 | 72.1 |

Table 8 Upper catchment forest covers by area.

| No. | Forest type | Area covered (ha) |
|---|---|---|
| 1 | Exotic species | 2828.3 |
| 2 | Mixed exotic and indigenous | 1224 |
| 3 | Indigenous species | 535 |
| **Total** | | **4500** |

## Diversity of tree species at household premises

Table 9 presents the most common tree species found on households' land in Addis Ababa. Other species were identified but not listed in Table 9 as they represented less than 1% of the total tree population. As indicated in Table 9 the commonest exotic tree species recorded was *Cupressus lusitanica*. However, this species is highly susceptible to attack by aphids that in turn have impacted on the attitude of tree planting among the communities around their gardens.

As shown in Figure 6 and Table 10 the largest age group of trees found at household level was between 31 and 40 years. This indicates that planting of trees is decreasing at a household level (i.e. a low proportion of trees at lower age classes and a high proportion of trees at a higher age class). To maintain city tree coverage a high proportion of trees at a lower age class and a low proportion of trees at a higher age class need to be planted.

Table 9 Most common tree species found on house holders land in Addis Ababa.

| Species | Total number of trees | Proportion of trees |
|---|---|---|
| *Cupressus lusitanica* | 2112 | 27.1% |
| *Dovyalis abyssinica* | 1474 | 18.9% |
| *Juniperus procera* | 1443 | 18.5% |
| *Vernonia amygdalina* | 751 | 9.6% |
| *Eucalyptus camaldulensis* | 494 | 6.3% |
| *Eucalyptus globulus* | 216 | 2.8% |
| *Juniperus* sp. | 133 | 1.7% |
| *Eucalyptus* sp. | 124 | 1.6% |
| *Eucalyptus citriodora* | 100 | 1.3% |
| *Ensete ventricosum* | 92 | 1.2% |
| Other species | 853 | 10.9% |
| **Total** | **7792** | **100.0%** |

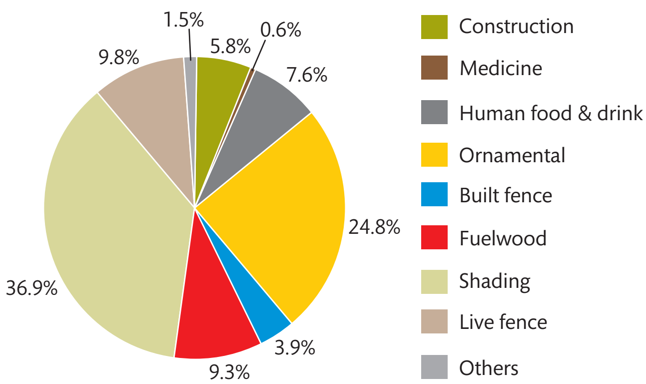
Figure 6 Proportion of households with trees by age group.


Table 10 Total, average number and age distribution of trees of households owning trees.

| Total and average number of trees for tree owners | | | | | Total and average number of trees for tree owners |
|---|---|---|---|---|---|
| | (0 to 10 yrs) | (11 to 20 yrs) | (21 to 30 yrs) | (31 to 40 yrs) | |
| Total | 1437 | 2221 | 1872 | 2262 | 7792 |
| Average | 4.1 | 6.4 | 5.4 | 6.5 | 22.4 |

As indicated in Figure 7, the highest proportion of trees planted at household level is used primarily for shade (36.9%) and ornamental purposes (24.8%). Consequently, to encourage tree planting at a household level tree species used for shading and ornamental purposes should be grown and distributed. Moreover, awareness creation should be made among the community to plant other multipurpose tree species such as *Prunus africana*, *Ekbergia capensis*, *Podocarpus falcatus* and *Hypericum revolutum* to enhance tree coverage, diversity and subsequent benefits.

Figure 7 Tree uses by households in Addis Ababa.



# Endemic and threatened woody species in the urban forest

The survey revealed that the urban forest of Addis Ababa is known to encompass 12 individual woody species of threatened and endemic plants of the country. These species are registered under a different category in the red list species. Species found in a red list are categorized as vulnerable, threatened or endangered. *Prunus africana*, a important medicinal tree species used to manufacture pharmaceuticals for the treatment of prostate cancer, has been found in churches and parks as well as naturally grown individual trees in the upper catchment forest area. This species has been registered in appendix II of the red data list by the Convention on Trade in Endangered Species (CITES).

Endemic species such as *Millettia ferruginea* are also an important component of the urban forest within Addis Ababa (Table 11). At present *Solanecio gigas* has been observed in a few remote and less developed areas of the city as a hedge mix with other species such as *Justicia schimperiana*. The conversion of hedge to concrete fences is aggravating the extinction of species such as *Solanecio gigas* which was once commonly found as a living fence in the forest area of the city.

# Medicinal woody plant species within Addis Ababa

Many species of medicinal plants are used in Addis Ababa, more than any other part of the country. Although many types of medicinal plant species are brought in from different agro-climatic zones of the country, a number of herbaceous, shrubby and tree species growing in the city are extensively used.

In addition to the use of existing medicinal plants to treat a wide range of health problems, traditional healers are also extensively using these plants for commercial purposes. This is due to the presence of large number of inhabitants in the city as well as migration of people with different cultures from different regions of the country. Such conditions enable the occurrence of diverse traditional knowledge in the use of medicinal plants. Furthermore, the accessibility of greater numbers of commercial traditional healers and modern medical facilities in the city has also contributed to the wider use of medicinal plants. Consequently, patients all over the country visit the city to receive these medicinal treatments. As a result, most of the identified woody medicinal plants are under severe threat as traditional healers are obligated to exhaustively use these once readily available but now scarce plants.

Though the medicinal value of these plants is well known, they are utilized in unsustainable ways. For instance, roots of *Carissa spinarum*, *Vernonia amygadalina*, *Bersama abyssinica*, *Olea europea*, *Meas lanceolata* and *Clausena aniseta* are used for the treatment of gastric ulcers, intestinal upsets, haemorrhoids, jaundice and infulenza. However, removing the root of a plant is a cause of whole plant death. Similarly, removing the leaves of plants affects photosynthetic ability and respiration, which in turn reduces survival of the plant. Some representative examples of parts of the plant used to treat health problems are presented in Table 12.

As shown in Table 13, in most church-yards more than 50% of tree species are exotic. Indigenous trees are often few in diversity and number. The dominant tree in all churches is the exotic *Cuprresus lusitanica* and the dominant indigenous tree is *Juniperus procera* followed by *Olea europea* subsp. *cuspidata*. Remaining indigenous trees are only one or two in number.

**Table 11** Endemic and/or threatened woody species of Addis Ababa.

| No. | Species | Family | Common name |
|---|---|---|---|
| 1 | *Inula confertiflora* A.Rich | Asteraceae | Wonagift |
| 2 | *Maytenus addat* (Loes.) Sebsebe | Celastraceae | Atat |
| 3 | *Rhus glutinosa* A. Rich. subsp. *glutinosa* | Anacardiaceae | Embus |
| 4 | *Rubus erlangeri* Engl. | Rosaceae | Yechaka enjori |
| 5 | *Echinops ellenbekii* O. Hoffm. | Asteraceae | Kosheshila |
| 6 | *Echinops longisetus* A.Rich | Asteraceae | Qeilo |
| 7 | *Erythrina brucei* Schweinf. | Fabaceae | Korch |
| 8 | *Solanecio gigas* (Vatke) C. Jefferey | Asteraceae | Yeshikoko Gomen |
| 9 | *Lippia adoensis* Hochst ex. Walp. | Verbenaceae | Kessie |
| 10 | *Millettia ferruginea* (Hochst.) Bak. subsp. *ferruginea* | Leguminaceae | Birbira |
| 11 | *Prunus africana* (Hook.F.) Kalkm | Rosaceae | Tikur Enchet |

Table 12 Some medicinal woody species found in the city and the parts used to treat different health problems.

| Species | Parts used | Disease treated |
|---|---|---|
| *Ficus thonningii* | Bark and root bark | Wounds, cold and influenza |
| *Carissa spinarum* | Root<br>Leaf and the seed | With goat milk used to treat gastric ulcer and chest complaints<br>Tooth ache |
| *Vernonia amygadalina* | Roots and stem<br>Bark of young twigs | Intestinal upset<br>Appetizer |
| *Cordia africana* | Roots and fruits | Ascaris |
| *Croton macrostachus* | Fruits and root<br>Roots | Venereal diseases<br>Purgative and malaria |
| *Bersama abyssinica* | Roots | Ascaris and rabies |
| *Olea europea* subsp. cuspidate | Roots | Haemorrhoids and intestinal complaints |
| *Hagenia abyssinica* | Female flowers | Remove tape worm |
| *Maesa lanceolata* | Root | Jaundice |
| *Clausena aniseta* | Root | Ascaris and influenza |
| *Dodonaea angustifolia* | Root and leaves | Hemorrhoids and wound dressing |

Table 13 Diversity of woody species in six inner city churches.

| No. | Church | Exotic | Indigenous | Total |
|---|---|---|---|---|
| 1 | Silase Arat kilo | 13 | 9 | 22 |
| 2 | Saint George (Pissa) | 8 | 8 | 16 |
| 3 | Saint Merry (Amist kilo) | 7 | 10 | 17 |
| 4 | Peteros paulos | 6 | 14 | 20 |
| 5 | Bole Medhanialem | 17 | 13 | 30 |
| 6 | Kechene Medehanialem | 8 | 8 | 16 |

During the assessment it was observed that the existing indigenous trees are aged and some only have a limited lifespan. Some species of aged trees become susceptible to natural hazards such as strong winds, storms and flooding. Old trees therefore need to be replaced by new indigenous tree seedlings to improve the metropolitan environment.

## Awareness level of the community

As illustrated in Table 14, rows 2 and 3, 67.7% of the respondents agreed that a urban forest located within their vicinity is considered as a place for sexual violence or hiding place for criminals. These facts discourage the community in and outside the forest to contribute to planting and protecting the tree from illegal cutting. Olembo and De Rham

Table 14 Social problem assessment on urban forest area.

| No. | Social problems | Respondents' category | | | | Total | |
|---|---|---|---|---|---|---|---|
| | | In the forest | | Outside the forest | | | |
| | | Frequency | % | Frequency | % | Frequency | % |
| 1 | As a physical threat to human safety | 8 | 5.9 | 6 | 4 | 14 | 4.9 |
| 2 | A hiding place for criminals | 46 | 34.1 | 45 | 30 | 91 | 31.9 |
| 3 | A place for sexual violence | 52 | 38.5 | 50 | 33.3 | 102 | 35.8 |
| 4 | A place for dumping industrial waste | 2 | 1.5 | 4 | 2.7 | 6 | 2.1 |
| 5 | A place for dumping domestic waste | 1 | 0.7 | 0 | 0 | 1 | 0.4 |
| 6 | Attracting dangerous wild animals | 0 | - | 2 | 1.3 | 2 | 0.7 |
| 7 | (2,3) | 9 | 6.7 | 13 | 8.7 | 22 | 7.7 |
| 8 | (1,2,3) | 3 | 2.2 | 15 | 10 | 18 | 6.3 |
| 9 | Has no problem | 14 | 10.4 | 15 | 10 | 29 | 10.2 |
| **Total** | | **135** | **100** | **150** | **100** | **285** | **100** |

(1987) stated that in most development endeavours the active participation of the concerned was the key to success. Thus, strong awareness creation and controlling criminals and sexual violence in the forest area should be given a higher priority.

## Conclusions

1. Encroachment by new settlement and removal of trees for various purposes is affecting the green coverage of Addis Ababa at an alarming rate. This problem is accelerated by low legal enforcement. Residents in Addis Ababa are poor. The use of forest products for fuel wood and to supplement income is high. There is also a serious lack of public awareness about the necessity and the environmental, social and economic benefits of trees. Consequently, the poor do not hesitate to cut down trees.
2. The selection of tree species for different purpose in the city has been poorly undertaken in the past. This has resulted in poor growth and a detrimental impact on infrastructure development. These problems are also due to lack of urban forest development guidelines for the city.
3. The contribution of the urban forest for floristic diversity was low since most of the plant species planted in the city area were uniform and focused on exotic species.
4. Although awareness creation is ongoing by different stakeholders to rehabilitate and develop urban forest in the city, there is a need for further awareness creation focused towards decision makers and the general public at all levels in order to develop and manage the forest resource.

## Recommendations

In order to have a sustainable urban forest in Addis Ababa the following recommendations are proposed:

- Guidelines to develop and manage the urban forest should be formulated.
- Intensive capacity-building programmes for concerned stakeholders should be carried out.
- Upper catchment management plans which benefit both regions should be developed to ameliorate the problem of boundary impact.
- Up-to-date comprehensive inventories of urban forests and tree resources across various ownerships in the city should be performed with a common inventory methodology.
- Development and construction authorities need to consult with the City Administration Environmental Protection Authority on activities impacting on forest resources.
- Environmental impact assessment procedures should be followed and improved cross-sectoral linkages and joint enforcement of environmental laws and standards should occur.
- Landscape proposals should be prepared for all development applications including housing, commercial, institutional and industrial development and given to the green area regulatory body.
- Further buffer zone encroachments should be controlled through strong legal enforcement. Frequent awareness creation programmes should be conducted for the sub-city and Kebele officials to reduce encroachment through using local level decision makers.
- A greater selection of appropriate species for roadside plantations and public gardens should be made.
- Involvement of stakeholders should be encouraged by concerned government offices.

## References

CENTRAL STATISTIC AUTHORITY (1999). Population and housing census report of Addis Ababa, Ethiopia.

CHIN, W.Y. AND CORLETT. R. (1986). *The city and the forest: plant life in urban Singapore*. Singapore University Press, Singapore.

El LAKANY, H. ed. (1999). *Urban and Peri-Urban Forestry: Case Studies in Developing Countries*. Food and Agriculture Organization, Rome.

GELDENHUYS, C.J. (1986). Costs and benefits of the Australian Blackwood, *Acacia melanoxylon*, in South African Forestry. *In*: Macdonald, I.A.W., Kruger F.J. and Ferrar, A.A. (eds.) *The ecology and management of biological invasions in Southern Africa*. Oxford University Press, Cape Town. 275 pp.

GILMAN, E.F. (1997). *Trees for urban and suburban landscapes*. Delmar Publishers. Albany, NY.

HANCOCK, G. (1995). *The beauty of Addis Ababa*. Camerapix Publishers International, Nairobi, Kenya.

OLEMBO, R.J. AND DE RHAM, P. (1987). Urban forestry in two different worlds. *Unasylva* **39**, 26–32.

WEBB, R. (1999). *Urban and peri-urban forestry in South- East Asia: A comparative study of Hong Kong, Singapore and Kuala Lumpur*. Food and Agriculture Organization, Rome.

# Innovations in urban forest governance in Europe

## Abstract

Governance has been defined in many different ways, for example as any effort to coordinate human action towards goals. One way of conceptualising governance is through a continuum ranging from 'governance by government', to 'governance with government', to 'governance without government'. While the first describes the dominance of hierarchical political action, the last describes political decision-making processes primarily relying on non-hierarchical forms of steering in the absence of a higher central instance and participation of government. Political modernisation encompasses shifting relations between state, market and civil society in the political domains of society.

This paper focuses on political modernisation in urban forestry governance in Europe. Governance aspects of urban forestry have had only limited attention from the scientific community so far, in spite of major changes driven by, for example, emerging political discourses, the call for more public involvement, and government reforms. A review of literature and cases shows that new forms and modes of governance are being set up to improve decision making about urban woodland, urban trees and other green spaces. These new forms of governance include, for example, integration of urban forestry issues within various governance domains, 'scaling up' of urban forestry issues and closer collaboration between different public bodies and government actors such as local and national authorities, and greater emphasis on public involvement. It also becomes clear, however, that there is limited comparative knowledge of this field.

## Introduction

A recent report commissioned by the Collaborative Partnership on Forests' Global Forest Expert Panels initiative (Rayner *et al*., 2010) outlines the complexity of modern-day decision making on forests. The report looks at strategic decision making on forest – with focus on the international arena – from a governance perspective, defining governance as any effort to coordinate human action towards goals. Forest governance involves a large and increasing amount of institutions, organisations, stakeholders and issues. The complexity of forest problems rules out simple governance solutions. Forest governance also considers issues such as the declining influence of the forestry profession in forest land decision making. In this respect, Hull (2011) speaks of the 'conundrum of forestry': 1) forests produce increasingly scarce and valuable goods and services that are increasingly at risk because of climate change, pests, diseases, urbanisation, exploitation, and neglect; 2) the confluence of rising value and rising threat presents a golden opportunity for professionals who can capture and enhance forest values, but 3) forestry's influence is eroding.

The governance aspects presented above also hold true for urban forestry, the interdisciplinary field that plans for and manages forest and tree resources in and near our cities and towns. Although the comprehensive planning, design and management of urban green spaces has a long history throughout Europe, application of the urban forestry approach as encompassing all trees and woodland areas in and around cities and towns has been much more recent (Konijnendijk, 2003). Urban forestry envisages integrating different elements of the urban green structure that have often been the domain of different professions and public authorities, for example trees along roads and on squares, parks and urban woodland. Moreover, urban forestry considers both public and private trees. Although the value of taking such an integrative perspective has been stressed, it has also become clear that decision-making processes are complex, for example due to the large amount of actors and stakeholders involved (Lawrence *et al.*, 2011). Moreover, urban forestry is typically dealing with so-called 'wicked problems', where no easy solutions are to be found.

**Keywords:**

discourse, policy, policy actors, urban forestry

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This article looks at strategic decision making on urban trees and woodland in Europe through the lens of 'governance', with governance encompassing the institutions, organisations, knowledge and processes involved in making policy and management decisions (Lawrence *et al*., 2011). Governance is broader than government and has been defined by Kjær (2010, p. 10) as 'the setting of rules, the application of rules, and the enforcement of rules', where rules refer to the political 'rules of the game'. In governance, actors are searching for control, steering and accountability. The aim of this contribution is to identify innovative governance solutions to dealing with complexity and wicked problems faced by urban forestry.

## Frame for analysing urban forest governance

As described above, governance is seen here as efforts – typically at the more strategic level – to direct human action towards common goals, and more formally as the setting, application and enforcement of generally agreed to rules. Several definitions of governance concentrate on 'governance by government', identifying the state and other public authorities as the *de facto* leading actors in decision making. Kleinschmit *et al*. (2009), however, stress that governance should be seen as much broader, ranging from 'governance by government', via 'government with governance', to 'governance without government', with forest governance showing trends towards more multi-actor decision processes.

Van Tatenhove, *et al*. (2000) have presented the Policy Arrangement Model (PAM) as one possible frame for analysing policy making and governance regarding for example forests and other natural resources. PAM provides a structured approach to analysing and understanding policy arrangements as the way in which a certain policy domain – such as urban forestry – is shaped in terms of organisation and substance. The model states policy arrangement can change according to four dimensions, namely 1) actors and their coalitions involved in the policy domain; 2) division of resources between the actors, relating to for example power and influence; 3) rules of the game; and 4) current policy discourses. In this paper, actors are described as organisations taking active part in urban forest governance, while the broader term of stakeholders refers to organisations and individuals that have a vested interest in urban forests, but are not actively involved in governance. 'Rules of the game' refer to institutions, and to the regulations, legislation and procedures relevant to a certain policy domain. Discourses are defined as sets of ideas, concepts and narratives which give meaning to a certain phenomenon in the real world.

Another central concept in the PAM is that of political modernisation in terms of shifting relations between state, market and civil society in the political domains of society. In the case of environmental governance, this can typically mean a policy arena with more actors and shifts away from 'government by government' towards more collaborative forms.

Earlier publications (e.g. Konijnendijk, 2003) have provided a more normative framing of the field of urban forestry, stressing the need for urban forestry to be 1) integrative, 2) socially inclusive, and 3) strategic, while 4) also embracing its urban mandate. Integration refers to looking 'horizontally' beyond sectoral and resource boundaries (e.g. from street tree to peri-urban woodland) as well as to 'vertical' integration of public authorities and other actors at different governance levels. Urban forestry's socially inclusive nature relates to equity issues and the wider involvement of stakeholders and urban residents. In order to find repercussion in a complex and highly dynamic governance setting, urban forestry needs to be strategic, formulating long-term visions and goals. Finally, while forestry has traditionally had a more rural mandate, its increasing urban framing requires fully engaging with urban societies and settings, and the challenges these pose.

The following sections will present and discuss developments and innovations (defined here as renewal in order to enhance process and performance) in urban forest governance in Europe related to these characteristics, using the governance terminology as outlined in this section.

## Innovations in urban forest governance in Europe

### Greater integration

A starting point for studying urban forest governance in Europe is studying how its policy domain is shaped – and how the field of urban forestry is defined. Definitions of urban forestry have changed over time. The way we look at and define concepts such as 'forest' is socially constructed and tells a lot about the way we look at the world. Elsewhere, more thorough analyses of (changing) definitions have been provided (e.g. Konijnendijk *et al*., 2006). There seems to be a trend towards more integrative urban forestry concepts, although there is still a focus on the 'forest ecosystem' (woodland) part in the way urban forestry is defined and applied in large parts of Europe. However, led by developments in the UK and Ireland, urban forestry is increasingly seen as looking at all urban and peri-urban tree resources. The Dutch city of Arnhem, for example, has been using the urban forestry approach as one of the underlying 'drivers' for developing a green strategy and 'green branding' of its city (Gemeente Arnhem, 2010). Another important development towards more 'urban green integration' is the rise in the use of the green infrastructure concept (e.g. Mell, 2010) as a way of stressing the need to take a comprehensive and functional view of green space, using the same 'language' as with other essential types of infrastructure. The Norwegian city of Bergen has been developing a 'blue-green' infrastructure plan for the period 2011–2020, with the clear ambition to integrate all its green and water structures, as well as to provide an input to city masterplanning and the overall political debate (Bergen Kommune, 2011; Lerum, 2011, pers. comm.). The discourse has thus been changing from 'single element' views of urban forests (typically city forests in many countries) to much more comprehensive concepts that include all tree, woodland and even all green space resources.

The emergence and spread of green infrastructure thinking has close links to the increasing focus on the functionality of forest and other ecosystems, as reflected in the ecosystem services discourse. From a governance perspective, the focus on ecosystem services arose with the United Nation's Millennium Ecosystem Assessment (2003). Rather than stressing the need to conserve nature and protect biodiversity *per se*, the discourse has gradually shifted to stressing the links between ecosystems, biodiversity and the essential services these provide to humankind. This discourse has also percolated to forest governance and urban governance as well as to governance on urban green space issues. According to the ecosystem services discourse, forests, trees, the overall 'urban forest' and the green infrastructure should be regarded as essential to urban societies, as they provide a range of supporting, provisioning, regulating and cultural services to society. Securing the provision of these services requires integrative and strategic planning and management. Moreover, adhering to ecological principles, it calls for a comprehensive perspective of all green spaces and elements in and around the city. This 'mainstreaming' of urban forest ecosystem services can be seen throughout Europe. Aesthetics and recreation are still an important part of the rationale for urban forestry, but a much wider range of goods and services is part of the discourse (Lawrence *et al.*, 2011). The role of urban forests in the climate change debate, and especially in terms of how they can make cities more resilient to climate change, is one case in point.

In line with the above, as well as with developments in government and public spending, greater integration is sought between different municipal departments, units and policies when urban forest issues are concerned. A national study of urban forestry in the UK identified the need for local authorities to integrate their governance and management of trees and woodland (Britt and Johnston, 2008). In Denmark, for example, a recent structural reform of government led to a merging of municipalities and the greater integration of planning and management tasks for both urban green space and forests and nature areas outside cities and towns. This has offered opportunities in terms of integration, but also challenges in merging different professional cultures and 'rules of the game' (Lerum, 2010).

Urban forest governance is also getting more integrated in terms of 'scaling up', both geographically and in terms of getting actors from different levels of government involved. An example of geographical scaling up has been the English Community Forests programme, a still rather unique effort of coordinating local urban and community forestry efforts at the national level. This programme has faced its difficulties, not least in terms of funding, but has also inspired similar initiatives elsewhere, such as Israel's Community Forests programme (Konijnendijk, 2008). Although urban forest governance is still mostly a local undertaking in most European countries, urban forestry and urban green space issues have emerged in national forest, nature and other policies. There has even been interest from the European Community level, for example by the recent use of the term 'green infrastructure' (European Commission, 2010) and organising a policy workshop on urban and peri-urban forestry as contribution to the implementation of the European Union Forest Action Plan.

An example of geographical scaling-up at the regional level is the Emscher Landscape Park (ELP) in the German Ruhr area. Led by a regional public body (the Regionalverband Ruhr) and increasingly also the federal state of North Rhine Westphalia, 20 years of planning and development together with municipal authorities and a range of other actors has led to a regional forested landscape park and a 'land transformation of unparalleled dimensions in terms of space, funding and time', in the words of Frank Bothmann, team leader at Emscher Landscape Concept (Under the open sky..., 2010). The ELP has helped transform a neglected area with abandoned industry to a green landscape with high-profile nature, recreation and cultural sites, covering an area of 85 km from east to west. The goal for the next two decades is to better link individual projects with one another and keep them going.

Examples of scaling-up in terms of greater involvement of regional and national actors at the local level of urban forest governance include the setting up of urban national parks in Sweden and Finland, the development of UNESCO Biosphere Reserves that include urban forest (such as the Wienerwald in Austria), and turning Zurich's Sihlwald urban woodland into an Urban Wilderness Park, with according status in national nature conservation legislation. All of these governance innovations involve state-level legislation and influence in local governance, which obviously brings along opportunities as well as challenges where local and national interests meet (Konijnendijk, 2008). The Slovenian town of Celje provides an interesting model of how city authorities and the state forest service have developed a partnership for urban forest planning and management. Jointly, they created a single brand for the city's urban forests, set joint objectives for management, and jointly engage with private forest owners in the area in order to bring these on board as well (Hostnik, 2011).

## More inclusive governance

Urban forestry programmes and projects throughout Europe have stressed the involvement of stakeholders and the public at large (Van Herzele *et al.*, 2005; Janse and Konijnendijk 2007). Van Herzele, *et al*. (2005) mention that much is to be gained from enhanced public involvement in decision making about one's daily living environment, for example in terms of more legitimacy and public support, enhanced awareness and 'better' decisions. The literature presents a large number of cases and experiences with public involvement in urban forestry, but it is difficult to assess how far stakeholder and resident involvement has become an integrated part of urban forest governance across Europe. Where public involvement in urban forests exists, this typically relates to (often statutory) policy making and planning, while involvement in actual management seems to be much less frequent. Cases of more organised forms of involvement, typically through associations and local resident organisations, are known (Van Herzele *et al.*, 2005; Janse and Konijnendijk, 2007). Performance indicators for the different English Community Forests, for example, have included information about the number of people involved in various activities, including planning workshops.

Although volunteering is widespread in many parts of European society (e.g. in sports clubs), only a few countries (notably the UK) seem to have traditions of large-scale volunteering in green space management and maintenance. The City of Copenhagen recently issued a first volunteering strategy specifically for open and green space and hopes to get local dwellers and associations more engaged in the maintenance of its open spaces. The city faces huge challenges, for example in terms of littering in its parks, and hopes that volunteering will help raise awareness about this problem as well as contribute to less expensive ways of dealing managing the problem (Københavns Kommune, 2010).

Public–private partnerships in urban forestry have also been discussed in different European countries, but these types of arrangements are restricted to green space maintenance, where private contractors carry out work for public authorities. More strategic partnerships such as those in the USA, where private conservancies or trusts are co-managing large urban parks such as Central Park in New York and Golden Gate Park in San Francisco, are less common in Europe. Exceptions are, for example, the Woodland Trust in the UK and the nature conservation organisations in the Netherlands, as these own and/or manage woodland areas in or near cities.

## More strategic governance

A study of green space management in the Nordic countries by Randrup and Persson (2009) identified a common trend among municipal green space departments regarding limited time and resources available for more strategic activities. Moreover, the authors found that green space departments or units are seldom directly linked to the political part of the municipal government, being at least one or two 'layers' away. This remoteness from political decision making could hinder attempts to bring urban green space issues on the political agenda. As urban forestry is often carried out by municipal green space departments, these findings are relevant to this field as well.

Having said this, municipalities across Europe have prepared more strategic visions and policies for their urban green spaces – although cities with a strategic vision for their green spaces still seem to be a minority, and a lot also remains to be done in terms of implementing grand ideas. Moreover, policies do not always include all elements of the urban forest – most notably private lands and trees are given only limited attention. The City of Copenhagen developed a 'park policy' for its green spaces several years ago and has gradually updated its strategic objectives. Other Danish cities have followed suit. The example of Bergen in Norway with its comprehensive 'blue-green' infrastructure strategy was described earlier.

In the green space governance discourse, the term 'urban forestry' is seldom used outside the UK and Ireland. An exception is the Dutch city of Arnhem, which specifically employs the 'urban forestry' concept of its strategic, cross-departmental efforts to develop its green structure and link up green space to overall city objectives. The city's Green Agenda, developed in an inclusive process that involves different parts of the municipality, experts and a range of organisations, now needs to be implemented (Gemeente Arnhem, 2010). Several UK cities and agglomerations have developed local community forest projects, where trees and woodland are the central elements of strategic agendas to develop and management multifunctional landscapes.

While governance of (publicly owned) woodland, parks and nature areas is becoming more strategic, resulting in a rapidly growing amount of visions, policies and strategies, urban trees are not always part of the policy discourse. An ongoing and unpublished Master-study in Denmark, for example, identified the lack of strategic consideration given to street-side and other urban trees, with tree care lacking expertise and often taking the form of 'crisis management'.

More strategic urban forestry governance also relies on sound knowledge management, for example as discussed by Lawrence *et al.* (2011). Here interesting collaboration models between municipalities and knowledge institutions have emerged in different European countries. So-called 'landscape laboratories' in Sweden and Denmark have been developed in collaboration between universities and municipalities to serve as test and demonstration areas for diverse and multifunctional woodland landscapes (e.g. Konijnendijk, 2008).

## Embracing an urban mandate

It seems obvious to embrace the urban when applying an urban forestry approach. But especially where forest and nature management are concerned, a key dilemma exists in terms of balancing the catering for urban demands with conserving natural resources and maintaining a certain 'naturalness'. Many woodland areas have gradually become parks, with an increasing amount of facilities, design and use. Former royal hunting estates are examples of this. Managers often ask the question, as a consequence, how 'urban' urban forestry should be. What types of activities should be allowed in urban forests? How much nature can there be? What are the experiences to be offered to urban residents? Questions like these are obviously also emerging in urban forestry governance discourses (e.g. Konijnendijk, 2003, 2008).

Embracing the urban also relates to the increasing need to generate income and reduce costs. With the western welfare model under pressure and public funding for green space management being cut, while demands for green space are growing and diversifying, the credo of 'more for less' is becoming a mantra throughout Europe. Can we generate more income from urban forestry, for example, by offering (and selling) a range of existing and new services? Here examples can be found of renting out parks for a wide range of events, from rock concerts to lifestyle fairs (Gehrke, 2001). City parks in Germany, for example, have attracted up to 25 000 people during parties and concerts.

While other professions involved in urban forestry, such as landscape architecture and horticulture, have been used to working in urban contexts, this is less so the case for forestry. This implies, for example, that innovations have been required in woodland management practices, focusing on other outputs of forestry than timber. Aesthetics and enhanced recreational values, for example, are mostly in focus. Moreover, with the discourse on ecosystem services, promoting the various environmental roles of urban forests also requires forestry's specific attention. Here quite some experience has been gained with protecting watersheds and drinking water reservoirs. The city of Vienna, for example, has owned forests more than 100 km away as 'water source protection forests' for a long time (Konijnendijk, 2003).

Also relevant in this context is the need to consider the lack of integration of urban, peri-urban and rural governance and planning.

Fully accepting the urban also implies that different 'languages' need to be used. In urban forestry discourses, (place) branding has also entered the scene, as cities and towns are competing for international and national liveability and 'green city' awards. Individual parks are being branded as well, to residents as well as tourists, following overseas examples such as Central Park in New York.

# Conclusion

Political modernisation in terms of changing relations between state, market and civil society in the political domains of society is also affecting urban forestry. From a traditional mode of governance that was very much 'command and control' by public bodies ('governing by government'), there is a development towards forms of governing with government. Governing without governance is not a widespread phenomenon, it seems. Kjær (2010) describes the general context of public sector governance reforms, for example through New Public Management reforms. Reforms comprise deliberately planned change to public bureaucracies, search for governance innovation, and have improvements in efficiency and effectiveness as expected outcomes. These developments will continue to have their impact on urban forest governance.

In terms of actors involved in urban forest governance, there is a trend towards a wider range of public, private and civic actors taking an active part. Policy networks are of rising importance and complexity (also Kjær, 2010), with public urban forest policy makers increasingly needing to operate in 'governance with government' settings, with tensions arising between flexibility and control. This shift is also requiring different institutional set-ups and rules of the game. Problematic for urban forestry is that its legislative base is often rather weak (Lawrence *et al.,* 2011). Changes are also occurring in the division of resources between different actors, with power and influence relations shifting. Some of the examples of this have been presented above.

In a recent article in the US-based *Journal of Forestry*, Hull (2011) provides an interesting perspective on the changes in the composition of forestry's 'patrons'. The traditional patrons, namely 1) government agencies charged with forest stewardship, 2) globalised forest industry and commodity producing landowners, and 3) remote rural landowners bypassed by urbanisation and forest investments have been losing influence. On the other hand, new patrons are gaining in importance, most notably 4) environmental non-governmental organisations, 5) owners of real estate investment forests typically located near urbanising areas, and 6) communities dependent on economies and services flowing from a working green infrastructure. In urban forestry, this development might be even clearer, as focus has been on a wide range of benefits and beneficiaries.

Hull (2011) sees opportunities for forestry with regards to this shift. He uses the concept of Working Green Infrastructure Forest (WGIF), stressing that both built (utilities, roads, buildings, markets) and green infrastructures are needed to sustain high quality lives and lifestyles, especially in urbanised areas. Urban dwellers are dependent on WGIF not for food, shelter or employment, but for ecosystem services and local sources of energy and materials they want to consume. WGIF acts as 'first contact' to forestry and natural resource management for millions of citizens, engaging, for example, challenges of climate change, green economy and wildfires. Urban forests thus can play an important role in aggregating or brokering ecosystem services and recreation, and even coordinating and distributing special forest products.

Finally, a study of the literature shows that we lack comprehensive knowledge of urban forest governance. There are very few studies, especially of a more comparative nature (James *et al*., 2009; Bentsen *et al*., 2010). While recent publications have addressed international national forest governance (Kleinschmit *et al.,* 2009; Rayner *et al.,* 2010), there is very limited attention for urban forestry in these reports and articles. The 'urban' part of forestry seems to be seen as less relevant to discourses such as the role of forestry in mitigating climate change. Lawrence *et al*. (2011) have argued in this respect that urban forestry risks falling between two stools, not being given attention by forestry, but also being caught between urban and rural governance and planning arenas.

## References


BENTSEN, P., LINDHOLST, A.C. AND KONIJNENDIJK, C.C. (2010). Reviewing eight years of Urban Forestry & Urban Greening: taking stock, looking ahead. *Urban Forestry & Urban Greening* **9**(4), 273–280.

BERGEN KOMMUNE (2011). *Blågrønn infrastruktur I Bergen – Grøntmiljøplan 2011-2020. Kommunedelplan*. Grønn Etat, Bergen Kommune, Bergen (in Norwegian).

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II. A new survey of urban trees in England and their condition and management*. Department of Communities and Local Government, London.

EUROPEAN COMMISSION (2010). *LIFE building up Europe's green infrastructure: Addressing connectivity and enhancing ecosystem functions.* DG Environment, EC, Brussels.

GEHRKE, M. (2001). Der Park als Veranstaltungsort: über Veranstaltungen im Grünen und Deren Verträglichkeit. *Stadt und Grün* **50**(5), 325–332 (in German).

GEMEENTE ARNHEM (2010). *Groene Agenda – De kracht van het groen (concept)*. [Online] Available at: http://www.arnhem.nl/dsresource?objectid=108039 [Accessed 05/03/11].

HOSTNIK, R. (2011). *The context of urban forests and the development of urban forestry in highly forested EU country: the experience of Celje, Slovenia.* Briefing paper submitted to the European Commission, DG Environment, for a workshop on urban and peri-urban forestry. [Online] Available at: http://ec.europa.eu/agriculture/fore/events/28-01-2011/hostnik_en.pdf [Accessed 10/02/11].

HULL, R.B. (2011). Forestry's conundrum: high value, low relevance. *Journal of Forestry* **109**(1), 50–56.

JAMES, P., TZOULAS, K., ADAMS, M.D., BARBER, A., BOX, J., BREUSTE, J., ELMQVIST, T., FRITH, M., GORDON, C., GREENING, K.L., HANDLEY, J., HAWORTH, S., KAZMIERCZAK, A.E., JOHNSTON, M., KORPELA, K., MORETTI, M., NIEMELÄ, J., PAULEIT, S., ROE, M.H. AND

SADLER, J.P. (2009). Towards an integrated understanding of green space in the European built environment. *Urban Forestry & Urban Greening* **8**, 65–75.

JANSE, G. AND KONIJNENDIJK, C.C. (2007). Communication between science, policy and citizens in public participation in urban forestry – experiences from the NeighbourWoods project. *Urban Forestry & Urban Greening* **6**(1), 23–40.

KJÆR, A.M. (2010). *Governance*. 7th edition. Polity Press, Cambridge.

KLEINSCHMIT, D., BÖCHER, M. AND GIESEN, L. (2009). Discourse and expertise in forest and environmental governance – An overview. *Forest Policy & Economics* **11**(5–6), 309–312.

KØBENHAVNS KOMMUNE (2010). *Frivillighed i det fri: Inspirationskatalog.* Center for Park & Natur, Teknik- og Miljøforvaltningen, København (in Danish). [Online] Available at: http://kk.sites.itera.dk/apps/kk_publikationer/pdf/761_icf6FiTJRa.pdf [Accessed 09/03/11].

KONIJNENDIJK, C.C. (2003). A decade of urban forestry in Europe. *Forest Policy and Economics* **5**(3), 173–186.

KONIJNENDIJK, C.C. (2008). *The Forest and the City: The cultural landscape of urban woodland.* Springer, Berlin.

KONIJNENDIJK, C.C., RICARD, R.M., KENNEY, A. AND RANDRUP, T.B. (2006). Defining urban forestry – A comparative perspective of North America and Europe. *Urban Forestry & Urban Greening* **4**(3–4), 93–103.

LAWRENCE, A., JOHNSTON, M., KONIJNENDIJK, C.C. AND DE VREESE, R. (2011). *The governance of (peri-)urban forestry in Europe.* Briefing paper submitted to the European Commission, DG Environment, for a workshop on urban and peri-urban forestry. [Online] Available at: http://ec.europa.eu/agriculture/fore/events/28-01-2011/lawrence_en.pdf [Accessed 10/02/11].

LERUM, S. (2010). *Hvordan har de danske bykommuner håndtert den grønne forvaltning etter at fylkesnivået ble borte ved kommunereformen i 2007?* Arbejdsrapporter, Skov & Landskab, Københavns Universitet (in Norwegian).

LERUM, S. (2011). Personal communication in the form of a presentation at an internal green space planning seminar organised by the Municipality of Bergen, Norway, 11 March 2011.

MELL, I. (2010). *Green infrastructure: concepts, perceptions and its use in spatial planning.* Doctoral dissertation, School of Architecture, Planning and Landscape, Newcastle University. [Online] Available at: https://theses.ncl.ac.uk/dspace/bitstream/10443/914/1/Mell10.pdf [Accessed 22/12/10].

MILLENNIUM ECOSYSTEM ASSESSMENT (2003). *Ecosystems and Human Wellbeing – A framework for assessment*. Island Press, Washington D.C.

RANDRUP, T.B. AND PERSSON, B. (2009). Public green spaces in the Nordic countries: Development of a new strategic management regime. *Urban Forestry & Urban Greening* **8**, 31–40.

RAYNER, J., BUCK, A. AND KATILA, P. (EDS.) (2010). *Embracing complexity: Meeting the challenges of international forest governance.* IUFRO World Series Vol. 28. IUFRO, Vienna.

UNDER THE OPEN SKY. EMSCHER LANDSCAPE PARK CONGRESS 2010 (2010). Departure into the Landscape. A special Topos publication. Supplement to *Topos* **73**.

VAN HERZELE, A., COLLINS, K. AND TYRVÄINEN, L. (2005). *Involving people in urban forestry – A discussion of participatory practices throughout Europe. In:* Konijnendijk, C.C., Nilsson, K., Randrup, T.B. and Schipperijn, J. (eds.) *Urban forests and trees – a reference book*. Springer, Berlin, pp. 207–228.

VAN TATENHOVE, J., ARTS, B. AND LEROY, P. (2000). *Political modernization and the environment; The renewal of environmental policy arrangements.* Kluwer Academic Publishers, Dordrecht.

# Governance and the urban forest

## Abstract

Governance can be defined as the stakeholders, institutions and processes involved in making policy and management decisions. Traditional forest governance in the United Kingdom (UK) involves the forest owner, government incentives and regulations, and occasionally the local community (e.g. through consultation over forest design plans). In contrast, in the urban context, the landowners, decision-makers and levels of public engagement are all much more diverse.

This paper presents an analysis of urban forest governance, which illustrates the range of challenges in which 'new meets old'. We conclude that while there are many examples of experimentation and innovation in developing the urban forest, it is important not to neglect the role of existing organisations, relationships and interests. Urban forestry needs to find a way of steering between radical change and existing structures.

To reach this conclusion we develop a framework for analysing urban forest governance in the UK, modified from a paper presented at a recent European Union Forestry Action Plan workshop. This framework consists of eight dimensions of governance: policies and laws; ownership, access and use rights; stakeholders and organisations; funding and delivery mechanisms; processes; knowledge management; and power. We illustrate this framework through a series of profiles of existing projects including the Community Forests (England), Cydcoed (Wales) and Woods in and Around Towns (Scotland), and compare ways in which these eight dimensions vary in these different contexts. This comparison across dimensions helps to highlight the innovative aspects within a project and to support learning across geographical and organisational contexts.

## Introduction

**Keywords:**

knowledge management, ownership, power, planning, policy, decision-making

The great majority of research about urban forestry tells us about the technical challenges, and the social benefits, of planting and managing trees in the urban context. But to make all of this happen – to get to the stage where individuals and organisations are producing and planting trees, and where the social and physical environment is improved through the results – requires effective governance. There has been a great deal of interest in forest governance over the last couple of decades, some of which is reflected in international legislation, but it has received less attention in the urban context.

This papers sets out a framework for thinking about urban forest governance, based on discussions at a recent European Union Forestry Action Plan (EUFAP) workshop on Urban and Peri-urban Forestry, organised by the European Commission Directorate General for Agriculture and Rural Development (Lawrence *et al.*, 2011). It uses the EUFAP briefing paper as the starting point to examine case studies from across the UK, and explore ways in which urban forest governance is evolving.

### What is forest governance?

Governance refers broadly to the processes and people involved in making decisions. There are different ways of thinking about governance. Some see it as a shift *from* government (i.e. hierarchical, top-down, centralised or specialised decision-making) *to* governance (i.e. more participatory, localised, partnership-based or distributed decision-making). Others see all of these as different kinds of governance. In a paper such as this, which seeks to explore what kinds of governance exist and how we can analyse them, it is more helpful to adopt a definition of governance which includes all of these.

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So, for our purposes, governance can be defined as the institutions, organisations, delivery mechanisms, knowledge and processes involved in making policy and management decisions.

Definitions of the urban forest itself include all the trees and woodland in and around urban areas (including street trees, gardens, parks, and community or local authority woodlands). Urban forest governance therefore refers to the structures, rules, partnerships and processes that shape decisions about urban and peri-urban trees and woodlands.

## What is special about urban forest governance?

Traditional forest governance in the UK involves the forest owner (plus or minus a forest manager), national government (through incentives and regulations), and occasionally the local community (through consultation over forest design plans). In contrast, in the urban context, the landowners, decision-makers and levels of public engagement are all more diverse, making forestry decisions more complex.

In the context of global shifts in forest governance, urban forest governance is progressive and innovative but has received relatively little attention (Lawrence *et al.*, 2011). Compared with traditional rural forest governance, urban forest governance involves a much wider range of stakeholders, interacting with state and non-state organisations operating at multiple scales. The urban forest is intensively used for a wide range of purposes; social uses are more prominent than in rural or traditional forestry; and the resource is made up of a diversity of components including woodlands, park trees, street trees and gardens.

Finally, there are specific issues around trees, which combine beauty with threat to property:

> *Trees are unlike anything else in that they take years, sometimes centuries, to create, but only a few minutes to destroy; they are usually beautiful, but at the same time can be a source of major problems; they are stationary, but cause problems by their movement; they are part of the land on which they were planted, and yet can encroach into other land; and they may outlive many generations. (*Mynors, 2002*)*

It is these features – the diversity and competing land use demands of the urban context, and the specific and contradictory qualities of trees and forests, that frame the issue of urban forest governance.

## The urban forest in the wider context of urban governance

Of course, urban forest governance is not the only field of experimentation in urban areas, which are characterised by rapid social change and innovation. Within this context, the idea of partnerships – between government and non-government, and across sectors – has been particularly significant over the last decade or more.

Very briefly, studies of urban governance focus on partnership, community empowerment, and the role of 'path dependency' or inherited institutional arrangements, and the contradictions and tensions between these (Fuller, 2010). The field is one that is evolving rapidly, and in recent times has been characterised in the UK as 'a period of institutional instability' with an uncertain future (Davies, 2004). At the same time, the real effectiveness of empowerment has been repeatedly questioned. Some propose that empowerment may need strong independent community organisation capable of challenging governing institutions rather than simply participating in networks (Davies, 2007).

## Urban forest governance: three challenges for integration

This area of governance relies on a particularly diverse body of legislation and policy – diverse across sectors, and diverse across scales.

Urban forests often 'fall between two stools' when it comes to legislation and policy, because of the diversity of resources (large woods, smaller woods, street trees, parks), ownership structures and administrative bodies. In many cases, there are no comprehensive policies for urban forests, but rather a patchwork of segmented policies, different spheres of interests and competition between different local authority/municipal bodies. Responsibilities for trees and woodlands are split between different departments, as demonstrated by research in many countries (Johnston *et al.*, 1999; Saretok, 2006; Britt and Johnston, 2008; Gerhardt, 2010). The information base for planning and management is often weak (Sangster *et al.*, 2011). Furthermore, conflicts over urban forests (and their use) have intensified and urban demands are rapidly changing.

A common thread across all of these governance components is the need for integration:

- across components of the urban forest and green spaces;
- between sectors;
- across scales (cities, urban/rural areas and countries).

Urban forestry would benefit from substantial integration and consolidation, and calls have been made for this (Britt and Johnston, 2008). However, urban forestry has seldom been subject to integrative policies (Konijnendijk, 2003; Knuth, 2005).

# A framework for analysing urban forest governance in the UK

The following framework is based on the dimensions of governance set out in the EUFAP paper (Lawrence *et al.*, 2011) with the addition of 'power'. Power is implicit in many of the dimensions (e.g. policies, stakeholders, tenure, process) but it is useful to describe it explicitly in order to explore more directly this aspect, which is often hidden.

In this section we describe the eight dimensions of governance more fully, and in particular relate them to conditions in the UK.

## Policies and laws

The legal and political rules and regulations that can affect urban forests and their management in the UK hail from statutes in an extraordinarily diverse range of sectors, including planning, forestry, nature conservation, plant health, transport, services/utilities and security. Additionally, there is considerable common and case law that applies to trees, the most important element of which is perhaps that relating to ownership. The result of this is a highly fragmented legal and political landscape with rights and responsibilities resting with many varied stakeholders, which Mynors (2002) describes as a 'wholly uncoordinated mixture'.

UK tree law has a long history; however, the majority of this has not applied to trees in urban environments. Whilst powers to plant trees have been vested in urban public authorities for some time (e.g. by the 1890 Public Health Amendments Act), this activity has only really occurred with the advent of town and country planning in the mid-20th century. Dandy (2010) concludes that legal aspects of governance do very little to encourage the retention or planting of street trees, and an examination of law relating to urban forestry more widely would likely yield the same result. In contrast, many legal structures, such as those relating to safety and utility services, encourage and facilitate the removal of trees from the urban environment.

Furthermore, departmental policies may actually conflict with each other. Tree officers may call for more street trees, whilst police or transport officials may object, and even demand the removal of trees, due to concerns over interference with CCTV security cameras or road safety. Laws can also impact upon people's interaction with urban trees with, for example, highway obstruction laws perhaps potentially affecting street tree use (Dandy, 2010).

This rather inadequate legal framework is counterbalanced, to some extent, by the now extensive organisational and corporate policy promoting the retention and planting of trees in urban areas. Regional policy has facilitated a number of urban and peri-urban forestry initiatives, often delivered in partnership (such as those delivering the Community Forests in England). Planning policy is also increasingly promoting urban forestry, albeit usually as a part of development, regeneration, urban greening and green infrastructure policy. Better still, some city authorities now have tree strategies which are parallel to and inform planning policies. The importance of urban trees is being increasingly recognised, which is useful in that it changes the debate and gets trees more prominently on the agenda.

Table 1 Key urban aspects of devolved forest strategies.

| Country | Strategy document | Examples of urban related policy |
|---|---|---|
| **England** | *A Strategy for England's Trees, Woods and Forests* (DEFRA, 2007) N.B. currently under review | Urban context mentioned throughout. One explicit aim is to create 'liveable neighbourhoods, towns and cities by using trees and woodlands as part of the green infrastructure which frames and connects urban and rural areas, improves the quality of a place, and regenerates brownfield and derelict land' |
| **Northern Ireland** | *Northern Ireland Forestry – a strategy for sustainability and growth* (Forest Service, 2006) | 'existing Woodland Grant Scheme will be revised, focusing new afforestation on agricultural land close to urban settlements and planned in a way that will facilitate future public access.' |
| **Scotland** | *Scottish Forestry Strategy* (Scottish Government, 2007) | The vision, outcomes and objectives are relevant in urban as well as rural areas. This is emphasised particularly under Outcome 1 (Improved health and well-being of people and their communities) and Outcome 3 (High quality, robust and adaptable environment) |
| **Wales** | *Woodland for Wales* (National Assembly for Wales, 2006) | Key outcome 6: Urban woodlands and trees deliver a full range of benefits. |

An important aspect of the policy context in the UK is the devolution of forestry to the constituent countries with the result that each has its own forest strategy. Key aspects of urban forestry in each are set out in Table 1.

## Ownership, access and use rights

Although much urban forestry takes place on public land, most land in cities is private, and trees on private lands, such as in gardens, are a vital element of the urban forest. In order to include such areas in policies and programmes that seek to enhance public benefit, different processes and incentives are needed to encourage owners to manage trees in a way that contributes to the urban forest. One policy tool available to stakeholders is to change tenure, that is the set of rights and responsibilities associated with the land and trees. For example, when a public body buys post-industrial land to develop a community forest, the land moves from private to public ownership. This potentially has profound impacts on access and use of the trees. Public use of urban trees and forests, even on public land, can be impacted upon by various aspects of governance, such as property rights, the potential for obstructing a highway and the informal social norms that influence individual behaviour (Dandy, 2010: 26–27). Another option is to offer increased incentives for urban forest establishment and management (e.g. premium woodland grant schemes) to take account of the higher opportunity costs in urban and peri-urban areas (Bateman *et al.*, 1996, Crabtree *et al.*, 2001).

Management of the complex mosaic of ownerships and use rights in the urban context is complicated by poor information. The *Trees in Towns II* (Britt and Johnston, 2008) report noted that only 19% of local authorities surveyed in England had an accurate record of the percentage of their district covered by trees and woodlands, and only 8% had an accurate record of the percentage of the total area of trees and woodland in their district that was either publicly or privately owned.

## Stakeholders and organisations

There has been a general trend for management of public urban space to be moved from local authority control towards direct or indirect involvement of other stakeholders (other public sector agencies, the private sector, community organisations and interest groups) (de Magalhães and Carmona, 2006). Successful urban forest governance relies on involving the right stakeholders, and these can be different from and far more diverse than stakeholders involved in 'traditional' forest governance in rural areas. The 'community' in cities is often less tangible, and consists of multiple and overlapping communities of place, interest and origin (Livingston *et al.*, 2010; Licari, 2011). In addition to residents and users of the area, there can be a multitude of interested government and non-government organisations, some with a strong emphasis on urban forestry (e.g. Trees for Cities (http://www.treesforcities.org) or Groundwork (http://www.groundwork.org.uk)). The objectives of these urban forestry stakeholders can, furthermore, be quite different from 'traditional' stakeholders with, often, far less emphasis being placed on pure economic objectives.

## Funding and delivery mechanisms

Financial support also affects the opportunities to create and maintain urban forests. Projects and programmes are specific to particular spaces and times, and have their own internal objectives and structures that shape outcomes. There is a need for evaluation of funding mechanisms for urban forestry, including income generation from benefits.

As noted above, the complexity of ownership and access in urban and peri-urban contexts makes it necessary to provide a mix of delivery mechanisms and incentives, including grants.

The general shift of urban governance towards multisector partnerships, mentioned in the introduction, also affects forestry, particularly in relation to urban regeneration policy. Partnerships can be seen as power-sharing fora or delivery mechanisms (Ambrose-Oji *et al.*, 2010). In the urban context they are often both (e.g. the Community Forests).

## Processes

A central tenet of urban forestry is the need for public participation, and the inclusion of a broad set of stakeholders. Urban forestry is already more socially inclusive than other types of natural resource management, and has been underpinned by the emergence of new types of institutions and networks to accommodate the organisational complexity. The actual processes used to involve the public and other stakeholders, and take account of their various interests, can range from consultations to more pro-active, grassroots forms of participation, and can draw on tools ranging from questionnaires to participatory mapping and planning. However, the use of these tools does not automatically lead to more participatory governance, as discussed in the section on power below.

## Knowledge management

One component of studies on governance has focused on knowledge management, particularly on the balance of 'expertise' and 'local' or 'lay' knowledge. These questions are relevant to issues about whose knowledge is required to make urban forestry happen.

Clearly technical knowledge is needed to ensure appropriate trees are planted in a place and manner that will ensure their survival, and as already noted this knowledge is often lacking (Sangster *et al.*, 2011) or split up across different departments and roles (Britt and Johnston, 2008).

Relevant knowledge is not always specialist knowledge. Citizen science, or the collection of data about trees, wildlife, or environment, through a network of volunteers is one example of the wider pool. The Natural History Museum (London) is gathering information about city trees through its Urban Tree Survey, which calls on volunteers to send in records of trees in various urban spaces, for example cemeteries.

## Monitoring and evaluation

Monitoring and evaluation data provides some of the richest sources of evidence through which urban forestry experience can be consolidated. However, a review of community forestry evaluation (much of it urban) in Great Britain concluded that the evidence is incomplete and project driven (Lawrence and Ambrose-Oji, 2011). There is a shift of focus from biophysical (tree planting) to social impact, but monitoring and evaluation still focuses on outputs rather than longer term and wider outcomes. Qualitative evidence for empowerment and enhanced community cohesion and creativity suggests a wider range of intangible benefits. Many experiences are documented only anecdotally.

## Power

At the core of many analyses of governance is the idea of a shift in power, away from centralised government towards sometimes various and dispersed non-governmental actors (Peters and Pierre, 2006), including communities.

Power can, in general terms, be conceptualised as the ability to achieve a desired outcome, although in policy analysis it has a relational / interactive dimension (Jessop, 1997; Sanderson, 2009), that is social and political actors are involved in relations where one has the ability to get others to behave in a way they would otherwise choose not to. Power can be exerted in various ways and at various levels. Actors are able to exert power over others' conduct through, for example, the threat of force, the creation of obligations or commitments or economic strength. Decision-making contexts can be shaped by actors setting the agenda and/or controlling the socio-cultural environment, which act to limit the ideas and opinions open to decision-makers.

Power relations permeate all aspects of urban forest governance from the obligations on tree owners created by legally binding liabilities through to planning committees' allocation of time for discussing tree issues on their agenda. The concept cuts across each of the elements identified in this section. Land (and hence tree) owners are perhaps the most powerful actors in urban forest governance (as is often the case in rural areas), due to their capacity to physically determine a tree's presence or absence in the landscape. This power is, to a certain extent, influenced by their legal obligations, and their economic capacity and knowledge to act. Organisations and individuals, particularly governmental bodies, that can define obligations, control engagement processes and/or have access to money and specialist knowledge can also be very powerful.

Communities, which are traditionally limited in economic and knowledge resources, are commonly less powerful. In some instances, urban regeneration initiatives can try to address power relations directly and explicitly – for example through the notion of community empowerment. However, the partnerships created by these initiatives can be tokenistic in this regard (MacLeavy, 2009). They can ignore or exclude some interests, instead promoting business and government agenda, and very rarely do they consist of genuine changes in power which would bind other actors to decisions taken by communities. This reflects a wider empirical critique of the governance concept, which questions the reality of claimed shifts away from centralised governmental power (Peters and Pierre, 2006).

Furthermore, while a move from local government control to more distributed control might be seen as self-evidently 'good' because more 'participatory', in fact there are many questions around the implications and accountability of those involved (de Magalhães and Carmona, 2006). In the wider context of discussion about the centrality of partnerships in urban governance, some question whether *more* participation can enhance the power of certain stakeholders at a cost to the representativeness of local government. Conversely, the focus on neighbourhood renewal and the importance of 'people' and 'places' has encouraged the emergence of a new form of 'community leader' who is seen as more in touch with the problems of local disadvantaged groups (Hemphill *et al.*, 2006).

Again power, participation and equitable representation do not necessarily map on to each other.

## Case studies

In this section we apply these eight dimensions of urban forest governance to some examples from across the UK, in order to build up a more systematic analysis of how governance approaches are developing.

### Cydcoed (Wales)

**Policies and laws:** Cydcoed, developed under the *Woodlands for Wales* 2001 strategy, was a programme which aimed to use community forestry to deliver social inclusion and to create social capital. It was targeted at Objective One areas of Wales (i.e. 'less prosperous areas' of the European Union, with GDP below 75% of the regional average), and was developed to help deliver Welsh Assembly Government aims to facilitate active community involvement in 'the environment' as a way to empower people, increase social cohesion, address health inequalities and provide work experience.

**Ownership, access and use:** 163 community groups linked up with land under a wide range of ownerships, but the majority (including most of the urban examples) were local authority owned.

**Stakeholders and organisations:** Forestry Commission Wales (FCW), the Cydcoed project team, community groups, project steering group. Initiatives ranged from small school grounds projects, through to those managed by tenants and residents associations and partnerships, to social enterprises and woodland businesses. Institutionally, although the Cydcoed team sat within FCW, it was originally positioned at 'arm's length'. This was intended to give it some autonomy, and also to help the team proceed unencumbered by the sometimes negative perceptions that communities hold of the Forestry Commission.

**Funding and delivery mechanisms:** Cydcoed was funded through the EU Objective 1 programme and the Assembly Government's Pathways to Prosperity scheme. The programme was aimed at communities classified by the Wales Index of Multiple Deprivation as being the most deprived and where there was no access to community greenspace for relaxation and exercise. It was a £16 million programme that gave 100% grants to 163 community groups across the West Wales and the Valleys region (Owen *et al.*, 2008). A key aspect of the project was that funding covered 100% of the community groups' needs. This was particularly valued by the groups, many of whom consisted of volunteers.

**Processes:** Within the scope of the overall programme, projects were very demand led. Project proposals were written by community groups; those that were successful then implemented them with support from project officers.

**Knowledge management:** Many of the groups were made up of volunteers with little experience of fund raising or project management. Project officers provided support in legal agreements, consultations, project development and planning, and long-term sustainability.

**Monitoring and evaluation:** A one-off, in-depth evaluation of the whole programme focusing on 24 community projects (Owen *et al.*, 2008). The report provides a wealth of detail including quantiative and qualitative indicators.

**Power:** Although there were issues around ownership and power-sharing on public land, many aspects of Cydcoed are seen as contributing to community empowerment. Funds were given directly to community groups themselves to manage and although professional help was available if required groups controlled and contracted services as needed. One group commented, 'Now that we have the money, the County Council has to listen to us!' In the case of Cydcoed there are significant learning points around the internal power structures of organisations. The Cydcoed programme was placed somewhat remotely from mainstream everyday business within FCW, and to some degree this led to difficulties in communicating the experiences of the project, and to achieving organisation 'ownership' of the important contribution made to social forestry.

[Sources: Owen *et al.*, 2008; Lawrence *et al.*, 2009]

### Mersey Forest (England)

**Policies and laws:** The Community Forests Programme in England was established in 1989 and focused initially on 12 urban areas. One of them, in northwest England, was the Mersey Forest. The 30-year Mersey Forest Plan sets a target of creating 8000 hectares of new community woodlands over its 30 years, bringing a wide range of environmental, economic and social benefits. This provides a policy framework for each local authority, enabling the implementation of policies and opportunities for changing land use. Since the launch of the Community Forests, new policy drivers have emerged which support them including social inclusion (or environmental justice), climate change and a focus on 'green infrastructure' formalised through spatial planning processes. Over time, the Community Forests have been increasingly seen as regional (rather than national) delivery mechanisms and have felt less supported by national policy.

**Ownership, access and use:** The programme has focused on use of a wide range of land including local authority land, public forest estate and privately owned land.

**Stakeholders and organisations:** The Mersey Forest Partnership includes seven local authorities as well as the Forestry Commission, Natural England and businesses including United Utilities. The Forest supports a network of 11 community groups who care for their local woodlands and get people involved long-term in their local environment. The then Department of the Environment was involved in approving forest plans.

**Funding and delivery mechanisms:** Initial funds from the Countryside Commission, along with FC Woodland Grant Schemes. Over time as central funding has reduced more effort has been directed to obtaining specific project-based funds to support the teams.

**Processes:** The Partnership, led by the local authorities, put in place 'core teams' (known as Forest Teams) to coordinate and enable activity. Their first tasks were to develop a long-term Forest Plan (30–40 years), to develop the Partnership, and to extend the interest and involvement to other groups and organisations. The Forest plans were developed with extensive public consultation and guidance from public bodies, and had to be approved by the then Department of the Environment, before start-up. As such, the processes were 'top-down' and bureaucratic, yet a wide range of community based projects have evolved within this framework .

**Knowledge management:** This varies across such a large project. Focusing on one example, Woolton Village Residents Association has gained accreditation to use land and woodland management equipment so that it is able to undertake tasks such as mowing and tree maintenance work on council owned land (Woolton Woods). Members of the group feel that success is based on proving to public agencies the ability of the community group to undertake complex tasks such as woodland management planning and mechanised maintenance tasks, and the support of third sector organisations such as the BTCV in relation to skills training and insurance.

**Monitoring and evaluation:** The Mersey Forest is well documented with abundant evidence (Lawrence and Ambrose-Oji, 2010). Indicators include basic quantitative measures such as number of people using woodlands, and number using woodlands at least once a week, combined with qualitative indicators and quotations from residents indicating an enhanced sense of place and community.

**Power:** This varies across such a large project and would merit further study. For example, Woolton Village Residents Association (Woodland Trust *et al*., 2011) noted that the group has come to a limit in terms of financial and activity capacity and needs to be looking at how to take things to the next level. They experience power resting with politicians who prevented the group from felling trees and entrepreneurial management.

[Sources: Lawrence *et al*., 2009; Mersey Forest, not dated)]

## Newlands Green Streets (northwest England)

**Policies and laws:** Newlands contributed to the delivery of policy at various scales including the Regional Economic Strategy, city/regions plans, Regional Forestry Framework and UK Sustainable Development Strategy and Sustainable Communities Plan.

**Ownership, access and use:** Green Streets focused on planting street trees, so 'ownership' rested with the local authorities acting as Highways Authority. By virtue of public location, access to and use of the trees is unrestricted.

**Stakeholders and organisations:** Green Streets adopted a broad partnership approach (which varied in composition between individual sites) and featured a strong community engagement effort (although the project fell slightly short of meeting all of its 'engagement' targets). There were many partner groups. Along with those representing sectors of the community and individuals, organisations included government bodies (e.g. Northwest Regional Development Agency [NWDA], Forestry Commission), environmental groups (Groundwork) and schools.

**Funding and delivery mechanisms:** Green Streets was funded via a combination of Newlands Project core funds (e.g. NWDA £300 000 2007–9) and 'match' funding from the European Union and local authorities.

**Processes:** Collaborations and partnerships were coordinated by project teams within two existing forestry organisations (Mersey Forest and Red Rose Forest). Community consultation processes varied between individual street sites, but successful examples included working with local groups (e.g. Black Environment Network) to engage and draw on local expertise.

**Knowledge management:** Use of 'visualisation' software to allow stakeholders and funders to see the final objective landscape. Local knowledge, particularly in relation to community consultation, was sometimes obtained from local community groups.

**Monitoring and evaluation:** The project was evaluated according to NWDA and match funders' criteria through an independent consultancy (Pathways Consulting). The Evaluation Report identifies some key recommendations (i.e. lessons learned) for future street tree project implementation.

**Power:** Residents were usually given the choice of whether to have a tree outside their home or not (through an 'opt-in' or 'opt-out' approach), and in a few cases were allowed to choose a tree. The Evaluation Report concluded that 'Our sense is that most people were informed but not consulted in any great depth *nor involved in shared decision making processes* regarding tree planting on their street.' (Pathways Consulting, 2009: 17) (our emphasis). Untrained individuals were, in the majority of cases, unable to participate in the actual tree planting itself given the practical difficulties, and safety issues involved, in doing so. While the consent of community groups and individuals was clearly a key concern, and may have prevented unwanted tree planting, it is clear that the final presence or absence of street trees in this project was determined by the funders, administrators and operational actors.

[Sources: primary research; Pathways Consulting, 2009]

## Trees and Design Action Group (London)

**Policies and laws:** This initiative works with the status quo – particularly in relation to urban design, and the place of trees in that, but has also influenced the development of the new London Plan.

**Ownership, access and use:** Public spaces, and trees in new developments in London.

**Stakeholders and organisations:** Arboriculturists, urban designers, architects, landscape architects, urban planners.

**Funding and delivery mechanisms:** Trees and Design Action Group (TDAG) is an informal forum, hosted by a commercial urban design company, and without direct funding. Delivery is through discursive process – in other words, stakeholders meet and share information about trees in urban design, and through the discussion process achieve understanding which then influences planning outcomes. The formalisation of TDAG as a partnership is currently being considered by members – with varying degrees of enthusiasm.

**Processes:** The discussion forum meets approximately every two months. Meetings are always well attended by core members and others.

**Knowledge management:** The aim of TDAG is to bring together different kinds of knowledge in order to increase understanding of trees in urban design. TDAG seeks to combine these different knowledges, at expert level. In particular, architects are seen as holding the most specialised and elite form of knowledge. Many architects are keen to include more (potentially large) trees in urban design but do not know how to. Therefore, they need to access the knowledge of arboriculturists.

**Monitoring and evaluation:** Currently informal. Evaluation is implicitly favourable in that the London TDAG is now being replicated in Birmingham and South Wales. In the words of one member, 'Participation in TDAG leads to a better quality of work, and enables us to influence the agenda.'

**Power:** The development of TDAG, and its success, is based on an explicit recognition that different status is given to different expert groups within the urban planning process. In the words of one former local authority tree officer, 'We are low down in the food chain.' Planners are much higher in the food chain. Architects and urban designers have more ability to influence the planners, so the tree officers need to work behind the scenes with these experts, in order to influence those who make the decisions.

[Sources: primary research]

## Woods in and Around Towns (WIAT, Scotland)

**Policies and laws:** In October 2003, the Forestry Minister asked Forestry Commission Scotland (FCS) to find ways of bringing woodland expansion and forestry benefits closer to where the people of Scotland live and work. The Minister identified three priorities for action:

- move the urban forestry agenda forward in Scotland, in partnership with local authorities and other stakeholders;
- build on progress being made with urban local authorities' indicative forestry strategies;
- secure examples of progress through pathfinder projects.

The WIAT Initiative is also a focus for developing FCS 'health and well-being' priorities in urban Scotland by:

- providing more opportunities to access woods for learning, activity and enjoyment;
- increasing the contribution of woodlands to the quality of our towns and cities; and
- increasing opportunities for communities to be involved in, and benefit from, management of their local woods.

**Ownership, access and use:** Mostly local authority owned; some National Forest Estate (i.e. FCS).

**Stakeholders and organisations:** Forestry Commission, local authorities, volunteers and friends groups.

**Funding and delivery mechanisms:** The WIAT Challenge Fund aims to bring urban woodland into sustainable management and improve recreation facilities by carrying out an agreed programme of work. Challenge funds derive from EU funding as part of the Scottish Rural Development Programme. The funding is targeted at woods within 1 km of settlements with a population of over 2000 people (the WIAT area). The aim is to regenerate the woodland environment close to centres of population, improving the quality of life for people living and working there. The type of work that could be supported includes:

- development of woodland management plans;
- silvicultural work to improve woodland structure and condition;
- construction of new or improved recreation facilities including footpaths.

**Processes:** Closely tied in with knowledge management and monitoring and evaluation – see below. The WIAT programme aims and processes have evolved through three generations. There is a strong focus on provision of operational support. For example, 'The grants will assist the two Councils to carry out initial tree safety, woodland management, path construction, way-marking and interpretation in 6 woods in Stirling.' (Clackmannanshire Council, 2007).

Top-down participation is implied. For example: 'The physical work on the ground will be complemented by events run by the Councils' Countryside Ranger Services and volunteer organisations to encourage local people to get out and about to enjoy, learn more about and get involved in volunteer tasks in their local woods.' (Clackmannanshire Council, 2007).

Within this structure there has been considerable reflexivity (policy learning) so that the aims and processes have evolved. This is summarised under 'monitoring and evaluation' below.

**Knowledge management:** A move from technical forestry knowledge, to incorporate landscape architects' knowledge, and from there an attempt to incorporate local perception and opinion.

**Monitoring and evaluation:** Has progressed through three levels:

- appraisal, i.e. 'identify problem' (2004); baseline study (2006) and output monitoring (2006 onwards);
- repeat on baseline (2009); owners survey (repeat of appraisal) (2010);
- (participatory) outcome monitoring (planning now, for implementation 2011).

**Power:** To date, relatively centralised decision-making; but the shifts in process described above point to explicit attempts to shift the balance of power from top-down attempts to encourage local involvement, to more locally led needs definition and control.

[Sources: interviews; Forestry Commission Scotland, 2006; Ward Thompson *et al.*, 2008; FCS website http://www.forestry.gov.uk/wiat]

## Conclusions

These case studies are only a small sample of the many projects which could have been profiled here, but they are ones that will be well known to many UK urban foresters and related professionals. By profiling each project under the same set of dimensions, we can start to see how particular components of governance are being used and developed in the UK.

While laws are relatively static in the examples given here, we can clearly see the range of scales at which **policy** is implemented, and the opportunities for learning across these scales. Even national programmes such as Cydcoed and WIAT are implemented in particular priority locations. These locations provide important contexts for such projects but there is rich potential for more cross-scale comparison.

Focusing on **ownership**, we see the great significance of local authorities across all contexts. Very little has been written about the role of local government in forest management, and a shift of attention to the urban context underlines the need for this. A study conducted in 2009 found that there is also very little analysis of how ownership and other formal aspects of governance affect the ways in which individuals and groups use urban forests and obtain various benefits from them.

It is perhaps surprising that the **stakeholders** in many of these examples are largely professionals. Cydcoed and the Mersey Forest provide contrasting examples, but some effort had to be made to find examples relevant to the 'urban' focus. We can take two immediate lessons from this: one is that 'community participation' is not as common as might be expected; the other is that interactions between professionals (and their professional/organisational cultures) are also challenging and merit particular attention.

Linked with this, the examples do not self-evidently illustrate particularly participatory **processes**, and even the examples which involve residents as stakeholders are government or expert led. **Knowledge management** also focuses on technical knowledge. The projects profiled here provide good examples of **monitoring and evaluation** but this is not typical of urban forestry in general.

All of this supports the need for a case-by-case analysis of **power**. In some cases local initiative is being blocked by existing power structures, some of which are perhaps subconscious, but others are more obvious to those facing them. Professional cultures, expertise and status are shown here as a significant component of these power relations, and affect stakeholder interactions, participatory processes and the application of knowledge.

The processes, actors and institutions involved in planning and developing the urban forest are often 'experimental' and 'innovative' – but perhaps they are not always consciously so, and we might be missing opportunities to learn from this innovation. Furthermore, it seems that some of these innovative aspects of urban forest governance arise simply from the need to work within existing structures and relationships, based on historical institutional structures and pathways to decision-making. To achieve its multiple goals, a more urban forestry, which involves more people more actively, needs to find a way of steering a path between radical change and existing structures.

## References


AMBROSE-OJI, B., WALLACE, J., LAWRENCE, A. AND STEWART. A. (2010). *Forestry Commission working with civil society*. Forest Research. [Online] Available at: http://www.forestresearch.gov.uk/fr/INFD-7WCDZH

BATEMAN, I.J., DIAMAND, E., LANGFORD, I.H. AND JONES, A. (1996). Household willingness to pay and farmers' willingness to accept compensation for establishing a recreational woodland. *Journal of Environmental Planning and Management* **39**, 21–43.

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II. A new survey of urban trees in England and their condition and management*. Department of Communities and Local Government, London. 647 pp. Executive summary (36 pp.) [Online] Available at: http://www.communities.gov.uk/publications/planningandbuilding/treesintownsii

CLACKMANNANSHIRE COUNCIL (2007). *Woods in and around Towns Project. press release, Wednesday 17 October 2007*. [Online] Available at: http://alva.inuklocal.co.uk/News/Woods-In-and-around-Towns-Project-999–136686-937

CRABTREE, B., CHALMERS, N. AND EISER, D. (2001). Voluntary incentive schemes for farm forestry: Uptake, policy effectiveness and employment impacts. *Forestry* **74**, 455–465.

DANDY, N. (2010). *The social and cultural values, and governance, of street trees.* Forest Research, UK. [Online] Available at: http://www.forestresearch.gov.uk/fr/INFD-8D4FJ8 [Accessed 18/01/11].

DAVIES, J.S. (2004). Conjuncture or disjuncture? An institutionalist analysis of local regeneration partnerships in the UK. *International Journal of Urban and Regional Research* **28**, 570.

DAVIES, J.S. (2007). The limits of partnership: An exit-action strategy for local democratic inclusion. *Political Studies* **55**, 779–800.

DE MAGALHÃES, C. AND CARMONA, M. (2006). Innovations in the management of public space: Reshaping and refocusing governance. *Planning Theory and Practice* **7**, 289–303.

DEFRA (2007). *A Strategy for England's Trees, Woods and Forests.* Department for Environment, Food and Rural Affairs. 42 pp.

FOREST SERVICE (2006). *Northern Ireland Forestry – a Strategy for Sustainability and Growth*. [Online] Available at: http://www.dardni.gov.uk/forestservice/strategy-for-sustainability-growth.pdf

FORESTRY COMMISSION SCOTLAND (2006). *Woods In and Around Towns – progress report*. [Online] Available at: http://www.forestry.gov.uk/forestry/infd-5w2nfz

FULLER, C. (2010). Crisis and institutional change in urban governance. *Environment and Planning A* **42**, 1121–1137.

GERHARDT, D. (2010). *A Survey of Urban Tree Management in Local Authorities in Germany*. MSc dissertation, Myerscough College. [Online] Available at: http://www.myerscough.ac.uk/?page=subjects-arboriculture-daniel-gerhardt-dissertation

HEMPHILL, L., MCGREAL, S., BERRY, J. AND WATSON, S. (2006). Leadership, power and multisector urban regeneration partnerships. *Urban Studies* **43**, 59–80.

JESSOP, B. (1997). The governance of complexity and the complexity of governance: preliminary remarks on some problems and limits of economic guidance. *In:* Amin, A. and J. Hausner, J. (eds), *Beyond Market and Hierarchy: Interactive Governance and Social Complexity*. Edward Elgar, Cheltenham, pp. 111–47.

JOHNSTON, M., COLLINS, K. AND RUSHTON, B. (1999). A Survey of Urban Forestry in the Republic of Ireland. *In: Proceedings of Ireland's Third Urban Forestry Conference, Galway City, 22–24 April, 1998*. The Tree Council of Ireland.

KNUTH, L. (2005). *Legal and institutional aspects of urban and peri-urban forestry and greening*. Food and Agricultural Organization of the United Nations (FAO), Rome. [Online] Available at: http://www.fao.org/legal/legstud/ls88/ls88e.pdf

KONIJNENDIJK, C.C. (2003). A decade of urban forestry in Europe. *Forest Policy and Economics* **5**(3), 173–186.

LAWRENCE, A. AND AMBROSE-OJI, B. (2011). Understanding the effects of community woodlands and forests in Great Britain. *In: Proceedings of the 18th Commonwealth Forestry Conference*, Edinburgh, UK, 28 June – 2 July 2010. [Online] Available at: http://www.cfc2010.org/papers/session11/Lawrence-s11.pdf

LAWRENCE, A., ANGLEZARKE, B., FROST, B., NOLAN, P. AND OWEN, R. (2009). What does community forestry mean in a devolved Great Britain? *International Forestry Review* **11**, 281–297.

LAWRENCE, A., JOHNSTON, M., KONIJNENDIJK, C. AND DE VREESE, R. (2011). *The governance of (peri-)urban forestry in Europe.* Briefing paper 3. Workshop on sharing experiences on urban and peri-urban forestry. 28 January 2011, Brussels. [Online] Available at: http://www.ec.europa.eu/agriculture/fore/events/28-01-2011/lawrence_en.pdf

LICARI, G. (2011). Anthropology of urban space: Identities and places in the postmodern city. *World Futures: Journal of General Evolution* **67**, 47–57.

LIVINGSTON, M., BAILEY, N. AND KEARNS, A. (2010). Neighbourhood attachment in deprived areas: Evidence from the north of England. *Journal of Housing and the Built Environment* **25**, 409–427.

MACLEAVY, J. (2009). (Re) analysing community empowerment: Rationalities and technologies of government in Bristol's new deal for communities. *Urban Studies* **46**(4), 849–875.

MERSEY FOREST (NOT DATED). *The Mersey Forest little book of messages*. [Online] Available at: http://merseyforest.org.uk/messages.pdf

MYNORS, C. (2002). *The law of trees, forests and hedgerows*. Sweet & Maxwell, London.

NATIONAL ASSEMBLY FOR WALES (2006). *Woodland for Wales*. [Online] Available at: http://www.forestry.gov.uk/pdf/EnglishWfWstrategy.pdf/$FILE/EnglishWfWstrategy.pdf

OWEN, R., POWELL, J., REED, M., KAMBITES, C. AND LEWIS, N. (2008). *An evaluation of Cydcoed: the social and economic benefits of using trees and woodlands for community development in Wales.* Forest Research. [Online] Available at: www.forestry.gov.uk/pdf/Cydcoed_final_report_Jan09.pdf/$FILE/Cydcoed_final_report_Jan09.pdf

PATHWAYS CONSULTING (2009). *Newlands Green Streets: pilot project evaluation report*. Northwest Regional Development Agency, Forestry Commission England and Newlands Project.

PETERS, B.G. AND PIERRE, J. (2006). Governance, government and the state. *In:* Hay, C., Lister, M. and Marsh, D. (eds.) *The State: theories and issues*. Palgrave, Basingstoke.

SANDERSON, I. (2009). Intelligent policy making for a complex world: pragmatism, evidence and learning. *Political Studies* **57**, 699–719.

SANGSTER, M., NIELSEN, A.B. AND STEWART. A. (2011). *The physical (peri)-urban forestry resource in Europe.* Briefing paper 2. Workshop on sharing experiences on urban and peri-urban forestry. 28 January 2011, Brussels. [Online] Available at: http://www.ec.europa.eu/agriculture/fore/events/28-01-2011/sangster_en.pdf

SARETOK, L. (2006). *A Survey of Urban Forestry in Sweden*. Honours dissertation, Myerscough College. [Online] Available at: http://www.myerscough.ac.uk/?page=subjects-arboriculture-urban-forestry-sweden [Accessed 22/12/10].

SCOTTISH GOVERNMENT (2007). *Scottish Forestry Strategy*. [Online] Available at: http://www.forestry.gov.uk/website/forestry.nsf/byunique/infd-6aggzw

WARD THOMPSON, C., ROE, J. AND ALVES, S. (2008). *Woods in and Around Towns (WIAT) Evaluation: baseline survey Phase 1B.* Report to Forestry Commission Scotland. OPENspace. [Online] Available at: www.forestry.gov.uk/pdf/WIATBaselineSurveyFinal300307.pdf/$FILE/WIATBaselineSurveyFinal300307.pdf

WOODLAND TRUST, MERSEY FOREST, FOREST RESEARCH AND LLAIS Y GOEDWIG (2011). *Civil society, communities and woodlands: emerging opportunities.* Workshop report. [Online] Available at: http://www.forestresearch.gov.uk/pdf/Communities_civil_society_and_woodlands.pdf/$FILE/Communities_civil_society_and_woodlands.pdf

# Does beauty still matter? Experiential and utilitarian values of urban trees

## Abstract

A major focus of early research on the social aspects of urban forestry was on how people perceive and value the beauty of trees in cities and towns. Since then, researchers have found that besides aesthetic enjoyment, the presence of urban forest vegetation may provide additional benefits such as stress relief, recovery from mental fatigue, stronger social ties, improved health and longevity, and reduced crime. Research has also documented that the urban forest can generate economic returns in the form of higher property values, increased retail activity, and reduced costs of heating and cooling, as well as environmental benefits like improved air quality. In their enthusiasm for these research findings on utilitarian tree benefits, some urban forest advocates have tended to disparage and belittle the aesthetic values of urban trees, suggesting that the beauty of urban trees is of trivial significance compared to their environmental, social, economic, and health benefits. But there is ample research evidence to show that beauty still matters as a reason for planting trees. Aesthetic values and utilitarian values of urban trees are both important, and they are interrelated. In fact, many of the utilitarian benefits of trees are a direct consequence of their beauty. Therefore, future research on urban forest values needs to give equal attention to both kinds of value. Rather than promote one at the expense of the other, urban forest advocates should highlight how these two kinds of value reinforce and support each other in enhancing the quality of urban life.

## Introduction: research on urban tree values

**Keywords:**

aesthetics, benefits, social values, urban forestry

Research on the social and aesthetic values of urban trees has been in progress for at least the last three decades. From its beginning, a major focus of this research has been on how people perceive and value the beauty of trees and forested environments in cities and towns. For example, early research on people's perceptions of urban environments in the USA found that trees and other vegetation are one of the most important positive features contributing to the visual aesthetic quality of residential streets, parks and neighbourhoods (Ulrich and Addoms, 1981; Anderson and Schroeder, 1983; Buhyoff *et al*., 1984). Studies using tree inventory data to assess the impact of trees on the public's aesthetic preferences for streetscapes in Ohio towns found that big trees have a much greater impact on perceived beauty than do smaller trees (Schroeder and Cannon, 1983), and that yard trees away from the street also contribute significantly to visual quality (Schroeder and Cannon, 1987). In most of this research, it was taken for granted that aesthetic quality is a significant value provided by urban trees, and that enhancing visual aesthetics is an important way in which urban forest management can benefit urban residents.

More recently, research has revealed that there are a variety of other ways in which city and town residents benefit from trees in addition to aesthetic enjoyment of the urban forest. Vegetation and other natural features of the environment appear to have physiological and psychological effects on humans that contribute significantly to mental and physical health and wellbeing. Researchers have found evidence that trees and other vegetation may reduce stress (Ulrich *et al.*, 1991), speed recovery from surgery (Ulrich, 1984), and enhance cognitive functioning by promoting recovery from mental fatigue (Kaplan, 1995).

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A series of studies on the social and psychological values of vegetation in Chicago public housing has shown that residents of buildings surrounded by trees benefit from increased social interaction with other residents (Kuo *et al.*, 1998), reduced levels of aggression (Kuo and Sullivan, 2001a), less crime and fear of crime (Kuo and Sullivan, 2001b), and improved ability to cope with stress (Kuo, 2001). Adolescent girls who spend time outdoors in settings with trees and vegetation exhibit higher levels of self-discipline (Taylor *et al*., 2002). Children with attention deficit disorder are better able to focus and learn after spending some time outdoors (Taylor *et al*., 2001).

Recent studies in Japan, the Netherlands, and England suggest that the restorative effects of experiencing nature and the opportunities that urban green spaces provide for physical activity may improve the public's general health (Maas *et al*., 2006), increase longevity (Takano *et al*., 2002), reduce morbidity (Maas *et al*., 2009), and mitigate inequalities in health due to disparities in income (Mitchell and Popham, 2007, 2008; Hartig, 2008).

In addition to the social, psychological, and health-related benefits cited above, research into the economic benefits of urban trees has documented that the urban forest can generate real revenue in the form of higher sales prices for residential properties (Anderson and Cordell, 1988), increased retail activity in shopping districts (Wolf, 2005), and reduced costs of heating and cooling (McPherson and Simpson, 2003).

There are two primary purposes motivating this research on the values of urban trees. The first purpose is to provide community planners and urban foresters with information they can use to improve planting and maintenance programmes so as to maximize the benefits that urban trees provide to the populace. The second purpose is to convince local officials and decision makers of the importance of planting and maintaining trees and other green infrastructure, so that urban forestry will be given a higher priority in budgeting, planning, and decision-making. In combination with research on the physical environmental effects of trees and vegetation (e.g. air quality improvements, carbon sequestration, moderation of temperature extremes, and stormwater retention), information on the social, health, and economic benefits of urban trees provides strong support for planting and managing trees as an essential component of environments where humans live, work, and recreate.

## Beauty belittled

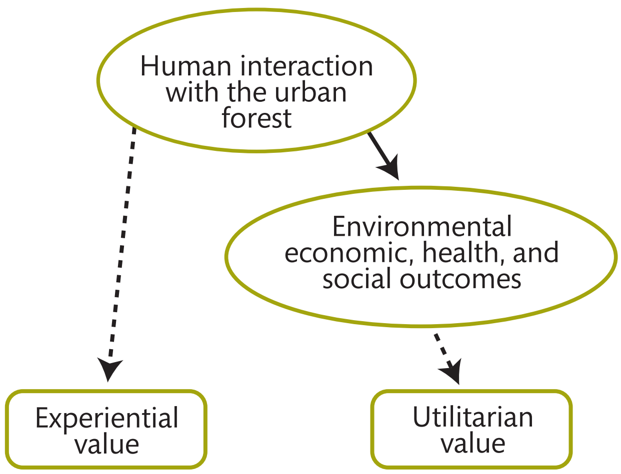
In their enthusiasm for these research findings on environmental, economic, social, and health-related benefits, however, some urban forest advocates have tended to disparage and belittle the more intangible and experiential values of urban trees such as aesthetics. Perhaps the most striking example of this is a speech given in the early 1990s by the chair of the National Urban Forest Council, Donald Willeke, in which he declared, 'Beautification be damned! Urban and community trees should be planted for economic, environmental and social reasons' (quoted by TreeLink, 2008). He went on to say that, because of the economic benefits of trees, he would urge their planting and maintenance in urban areas 'even if they were ugly and smelled bad' (quoted by Baxter, 2008, p. 9). Willeke's words have been echoed by other urban tree advocates and still appear on the websites and in newsletters of many urban forestry advocacy groups. In an article about economic benefits of urban trees, Provenzano (2008, p. 37) quotes Willeke and declares 'Ah, yes, trees are indeed beautiful, and the aesthetic appeal cannot be overstated, but we are talking about so much more than just a pretty face here.' Remarks like this seem to imply that the aesthetic value of urban trees is a superficial amenity and is of minor concern compared to their environmental, social, health, and economic benefits.

The beauty of trees has traditionally been a prime reason for planting them in cities, and aesthetic experience is perhaps the most immediate way in which most urban residents are aware of the value of the urban forest. But as our understanding of the economic, social, environmental, and health benefits of urban trees has increased, some urban forestry advocates seem to have decided that beauty does not really matter as a reason for planting trees.

## Two kinds of value

To clarify the issue, it may be helpful to point out that there are two basically different ways in which value can arise from people's contact with the urban forest (see Figure 1). On the one hand there are the feelings of pleasure, enjoyment, and appreciation that arise directly from people's immediate experience of trees and other natural

**Figure 1** Two ways in which value can arise from people's contact with the urban forest.



features in their environment. I call this *experiential value*, of which aesthetic value is probably the most well-known instance. Experiences of peacefulness and serenity, the feeling of being close to nature, a sense of place, and even (for some people) spiritual experiences could also be counted as experiential values of urban forests.

On the other hand, human contact with urban forests may lead to additional outcomes, which also have value for people. I call this the *utilitarian value* of the urban forest. The outcomes that have utilitarian value may be grouped into the four broad categories shown in Table 1. In the case of utilitarian value, the urban forest itself is not immediately a source of value to people; rather the various outcomes and benefits that arise from human contact and interaction with the urban forest are what is valued. A person or community might enjoy these outcomes and benefits without even knowing that they are due to the presence of trees and other natural features in the environment.

Table 1 Utilitarian outcomes of human interaction with urban forests.

| Category | Examples |
|---|---|
| Environmental | • Improved air quality<br>• Reduced flooding<br>• Carbon sequestration |
| Health | |
| Physical | • Increased cardiovascular fitness from outdoors exercise |
| Mental | • Reduced stress<br>• Improved cognitive function |
| Economic | |
| New revenue | • Higher residential property values<br>• Increased retail activity |
| Cost savings | • Reduced heating and cooling costs |
| Social | • Stronger community ties<br>• Reduced violence and crime |

The basic question then is this: with all that we have learned and are continuing to learn about the many utilitarian values that urban trees provide, should we now conclude that the aesthetic and other experiential values of the urban forest are not important as a reason for planting and maintaining trees? Does the beauty of the urban forest still matter?

## Research supporting the importance of beauty

I believe there is ample evidence from research to show that beauty and other experiential values of the urban forest do indeed still matter. Studies in the USA and England have asked homeowners to rate the importance of various benefits and annoyances that they experience from the trees in the vicinity of their houses. These studies found that visual beauty is considered by homeowners to be the most important benefit provided by street trees. The pleasing appearance of street trees is consistently rated by homeowners as more important than utilitarian benefits such as improved air quality, cooling of the home, reduced wind speed, and increased property value (Sommer *et al.*, 1990; Schroeder and Ruffolo, 1996; Flannigan, 2005, 2010; Schroeder *et al.*, 2006; ). These studies show that people generally have very high levels of satisfaction with the trees by their homes, and that the importance of the trees' benefits outweighs any annoyances they create. Most recently, Flannigan (2010) expanded on these findings by means of qualitative data, revealing that aesthetics and other experiential values of neighbourhood trees are very important to householders in the southwest of England. In addition to visual beauty, the sounds and smells associated with street trees give people a sense of connection with nature, bringing a feeling of the rural countryside into their urban environment.

Research on aesthetic experience of the environment and sense of place shows that experiences of beauty involving natural features of the landscape have an immediate and significant impact on people's quality of life. For example, in studies in which people kept diaries of aesthetic experiences in outdoor settings (Chenoweth and Gobster, 1990; Gobster and Chenoweth, 1990), aesthetic experiences – many of which involved natural features of the landscape – were among the most highly valued experiences that the participants had during the course of their week. Interviews with older park users (Tinsley *et al.*, 2002) revealed that the most important perceived benefit from using city parks was 'an immediate sense of pleasure or gratification.' A total of 82% of participants rated this as a 'very important' or 'extremely important' benefit of their park use (Tinsley and Tinsley, 2001).

Open-ended surveys about people's special outdoor places (Schroeder, 2002, 2007) found that beauty is one of the most frequently mentioned qualities of places that people consider to be memorable or important to them personally. As illustrated by the following quotes, aesthetic and other kinds of positive experiences in these places are not merely a superficial amenity. They serve as significant sources of meaning and happiness in people's lives, leading people to form strong emotional attachments to the places where they occur.

*There are so many beautiful nature preserves and lands to explore, and I have. They all have natural beauty that fills me with joy, just to behold it.*

*What an uplifting experience it is to come here in early spring when the old oaks are outlined against the sky.*

*This beautiful spot restores my soul and makes me glad to be alive.*

The aesthetic quality of trees is an important part of the character of many urban places, and people may feel intense emotional distress and grief when faced with the loss of trees that have been a part of their community for most of their lives. In interviews with Charleston, South Carolina, residents about the losses they suffered during a major hurricane (Hull, 1992), the city's trees were among the most frequently described significant features that had been damaged by the storm. People expressed strong positive emotions for the trees that were lost. The trees' aesthetic value and their contribution to community image were the most commonly mentioned reasons why residents valued them. Some of the interviewees were almost in tears as they described the trees that had been lost.

Riddell and Pollock (1999) interviewed residents of a Chicago neighbourhood in which most of the mature trees were removed over a few days' time due to an invasion of Asian longhorned beetle. The residents spoke of the trees in much the same way as they would old friends and family members. The aesthetic and experiential value of the trees was an important part of their life in the neighbourhood, and the loss of that value was traumatic to many. At the urging of local residents, the City went to considerable expense to plant larger-diameter replacement trees so that the neighbourhood streetscape could regain its former character more quickly.

## Relationship between utilitarian and aesthetic values

Both aesthetic values and utilitarian values of urban trees are important, and they are intertwined with each other. In fact, many of the utilitarian values of urban trees extolled by Willeke and others are a direct consequence of their aesthetic value – although this is often not acknowledged. For example, a newsletter feature about economic benefits of urban trees (Nashville Tree Foundation, 2007) quotes Willeke on 'beautification be damned', and then lists increased shopping revenues, higher office occupancy rates, and increased home prices as examples of how trees add to the economic value of urban property. But these economic values exist in large part because the trees are beautiful. Trees increase property values and attract people to shopping districts and offices largely by virtue of their beauty. Furthermore, if trees were ugly and smelled bad, the potential of trees for reducing the consumption of fossil fuels for heating and cooling would likely not be realised, since people would not want to plant them near their homes. The beauty of trees and other natural things is part of what attracts people to go outdoors and engage in activities like walking and bicycling, which can improve cardiovascular health and reduce obesity. Similarly, in urban housing projects where aesthetically attractive outdoor spaces with trees and grass are available, residents are more likely to spend time outdoors where they can meet their neighbours, form social ties, and deter crime (Kuo 2003). If trees were not beautiful, most of these utilitarian benefits would be eliminated or greatly reduced.

However, even if beauty did not give rise to utilitarian benefits, it would still matter. Experiencing beautiful places and things has an immediate positive impact on a person's quality of life. The mere fact that people historically have chosen to plant trees in cities testifies to the experiential appeal that they have for urban residents. Why, then, would advocates for planting urban trees wish to belittle their aesthetic value? Perhaps it is because aesthetic values are inherently subjective, and our modern culture has an ingrained bias toward things that are tangible, objective, and measurable. Perhaps it is because experiences of beauty can be very difficult to capture in words. We know from our immediate experience that beauty matters, but when someone asks why, we may be at a loss to give a rational explanation or justification. Maybe it is also because aesthetic experiences can be very personal, making people reluctant to talk about them in a public forum where they can be criticised and judged by others. Therefore, people may feel a need to use more impersonal, objective information to argue for the things that they feel are important.

However, there is a potential risk in relying too heavily on research about utilitarian values to justify planting and management of urban trees. Many of the social, environmental, and health-related benefits being attributed to urban trees are in fact quite difficult to establish scientifically due to the multitude of complex factors that must be taken into account. Studies that do not adhere to very high standards of rigour in controlling for factors such as income, cultural differences, and self-reporting bias may be subjected to criticism that could ultimately weaken the argument for urban forestry (e.g. Adams and White, 2003). The exuberant claims now being made for tree benefits may sound frankly incredible to many members of the public, and the fact that much of this research is being funded and carried out by outspoken advocates for urban nature might lead some people to be sceptical of the results.

In research about the health benefits of foods and dietary supplements, it has often been the case that early, positive findings are not borne out by later, more extensive and rigorous studies. Early reports about vitamin E, for example, suggested that it could significantly reduce the risk of heart disease and cancer, and this prompted many people to start taking vitamin E supplements. Later, more rigorous research, however, was not able to confirm most of the beneficial effects that had been enthusiastically claimed for vitamin E, and the current state of knowledge about this nutrient remains unclear (National Institutes of Health, 2009). A similar fate may be in store for some of the health benefits of trees touted in recent studies. If the argument for planting trees is framed exclusively in terms of such benefits, then the argument may be undermined if later studies do not fully confirm the sweeping claims that are being made at present.

One advantage of beauty as an argument for planting urban trees is that aesthetic value is a matter of immediate, personal experience. One does not need a scientific study to know that trees are beautiful and that beauty contributes to one's quality of life. Unfortunately, people often do not fully appreciate this until after they have experienced a serious loss, such as in the spread of Dutch elm disease and the current widespread outbreaks of emerald ash borer in the USA.

Admittedly, not everyone is equally attuned to aesthetic experience, and some may indeed view aesthetics as a frivolous reason to plant trees. Local officials working with limited budgets may understandably be reluctant to spend money on trees without some evidence of a tangible, measurable return on their investment. A growing body of replicable scientific evidence about the utilitarian benefits of urban trees may be the most effective means of winning these people's support for urban forestry. But this in no way requires that the importance of aesthetic values be disregarded or belittled.

## Future research

Research on the utilitarian environmental, health, economic, and social benefits of trees needs to proceed carefully and rigorously. The influences of the environment on individual people and communities are complex and far from completely understood. This is illustrated in a recent study by Mitchell and Popham (2007). Using census data for self-reported health of all residents of England, they found an overall positive correlation between health and the quantity of nearby greenspace, but the relation varied depending on the income and the urban, suburban, or rural character of an area. There was no relationship between health and greenspace within higher-income suburban and rural areas, and in lower-income suburban areas there was actually a negative correlation between greenspace and health. One possible explanation for this is that lower quality greenspace, which may be more prevalent in low-income districts, might actually be detrimental to health. This suggests that the relationship between greenspace and health is not simply a case of 'green is good'. Researchers and urban forest advocates should therefore be careful to critically evaluate the findings of new studies and avoid drawing sweeping or simplistic conclusions until early research results have been adequately tested and replicated.

As our knowledge of the utilitarian benefits of urban forests matures, the beauty of urban trees should continue to be celebrated as an important value. Research should be directed to learning more about what kinds and configurations of trees have the greatest aesthetic value for which groups of people. Here again the issue is complex, as there appear to be significant differences in preferences among people from different countries, regions, and cultures (Fraser and Kenney, 2000). In a comparison between householders in the Midwestern USA and the southwest of England, the aesthetic value of trees was important to both groups, but homeowners in that part of the USA tended to like very large and fast-growing trees in front of their homes while the residents of southwest England preferred smaller and slower growing street trees (Schroeder *et al.*, 2006). It appears that aesthetic preferences are conditioned by a variety of factors, including differences in climate and housing density as well as cultural norms. To broaden our understanding of experiential values of urban forests, more studies need to be conducted in countries other than the USA, which is where most such research has been done to date, and more qualitative research is needed to understand in depth how urban people experience both the benefits and the annoyances of trees near their homes (Flannigan, 2010).

## Conclusion

Future research on urban forest values needs to give equal attention to both aesthetic and utilitarian values. Rather than promote one kind of value at the expense of the other, urban forest advocates should highlight how these two kinds of value can reinforce and support each other in enhancing the quality of life of urban people.

# References


ADAMS, J. AND WHITE, M. (2003). Health benefits of green spaces not confirmed. [Letter to the editor] *Journal of Epidemiology and Community Health* **57**, 312.

ANDERSON, L.M. AND CORDELL, H.K. (1988). Influence of trees on residential property values in Athens, Georgia (U.S.A.): a survey based on actual sales prices. *Landscape and Urban Planning* **15**, 153–164.

ANDERSON, L.M. AND SCHROEDER, H.W. (1983). Application of wildland scenic assessment methods to the urban landscape. *Landscape Planning* **10**, 219–237.

BAXTER, B. (2008). *Chestnut memories: oral history transcript*. Interview transcript. University of Tennessee, Chattanooga, Tennessee, USA. [Online] Available at: http://www.cs.uky.edu/~tony/BNB_WEB/25th%20Annual%20Meeting/Don%20Willeke.pdf [Accessed January 2011].

BUHYOFF, G.J., GAUTHIER, L.J. AND WELLMAN, J.D. (1984). Predicting scenic quality for urban forests using vegetation measurements. *Forest Science* **30**, 71–82.

CHENOWETH, R.E. AND GOBSTER, P.H. (1990). The nature and ecology of aesthetic experiences in the landscape. *Landscape Journal* **9**(1), 1–8.

FLANNIGAN, J. (2005). An evaluation of residents' attitudes to street trees in southwest England. *Arboricultural Journal* **28**, 219–241.

FLANNIGAN, J. (2010). *An investigation of residents' relationships with street trees in southwest England*. PhD Thesis. Birmingham City University, Birmingham, UK.

FRASER, E.D.G. AND KENNEY, W.A. (2000). Cultural background and landscape history as factors affecting perceptions of the urban forest. *Journal of Arboriculture* **26**, 106–113.

GOBSTER, P.H. AND CHENOWETH, R.E. (1990). Peak aesthetic experiences and the natural landscape. *In: Proceedings of the Twenty-First Annual Conference of the Environmental Design Research Association (Champaign-Urbana, Illinois, USA, 1990)*. EDRA, Inc., Oklahoma City, Oklahoma, USA.

HARTIG, T. (2008). Green space, psychological restoration, and health inequality. *The Lancet* **372**, 1614–1615.

HULL, R.B. IV (1992). How the public values urban forests. *Journal of Arboriculture* **18**, 98–101.

KAPLAN, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology* **15**, 169–182.

KUO, F.E. (2001). Coping with poverty: Impacts of environment and attention in the inner city. *Environment & Behavior* **33**, 5–34.

KUO, F.E. (2003). The role of arboriculture in a healthy social ecology. *Journal of Arboriculture* **29**, 148–155.

KUO, F.E. AND SULLIVAN, W.C. (2001A). Aggression and violence in the inner city: Impacts of environment via mental fatigue. *Environment & Behavior* **33**, 543–571.

KUO, F.E. AND SULLIVAN, W.C. (2001B). Environment and crime in the inner city: Does vegetation reduce crime? *Environment & Behavior* **33**, 343–367.

KUO, F.E., SULLIVAN, W.C., COLEY, R.I. AND BRUNSON, L. (1998). Fertile ground for community: Inner-city neighborhood common spaces. *American Journal of Community Psychology* **26**, 823–851.

MCPHERSON, E.G. AND SIMPSON, J.R. (2003). Potential energy savings in buildings by an urban tree planting programme in California. *Urban Forestry and Urban Greening* **2**, 73–86.

MAAS, J., VERHEIJ, R.A., DE VRIES, S., SPREEUWENBERG, P., SCHELLEVIS, F.G. AND GROENEWEGEN P.P. (2009). Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health* **63**, 967–973.

MAAS, J., VERHEIJ, R.A., GROENEWEGEN, P.P., DE VRIES, S. AND SPREEUWENBERG, P. (2006). Green space, urbanity, and health: how strong is the relation? *Journal of Epidemiology and Community Health* **60**, 587–592.

MITCHELL, R. AND POPHAM, F. (2007). Greenspace, urbanity and health: relationships in England. *Journal of Epidemiology and Community Health* **61**, 681–683.

MITCHELL, R. AND POPHAM, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet* **372**, 1655–1660.

NASHVILLE TREE FOUNDATION (2007). *Tree talk*, April 2007 [newsletter], Nashville Tree Foundation, Nashville, Tennessee, USA. [Online] Available at: http://www.nashvilletreefoundation.org/pdfs/april07news.pdf [Accessed March 2011].

NATIONAL INSTITUTES OF HEALTH (2009). Dietary supplement fact sheet: vitamin E. National Institutes of Health, Office of Dietary Supplements, Bethesda, Maryland, USA. [Online] Available at: http://ods.od.nih.gov/factsheets/vitamine/ [Accessed February 2011].

PROVENZANO, P. (2008). Money does grow on trees. *Land Development Today* **4**(7), 36–37.

RIDDELL, J. AND POLLACK, N. (1999). *Views on the Asian longhorned beetle infestation in Chicago: an exploration of insights from neighbors and government*. Final report 23–99–10-RJVA. USDA Forest Service, North Central Forest Experiment Station, Evanston, Illinois, USA.

SCHROEDER, H.W. (2002). Experiencing nature in special places. *Journal of Forestry* **100**(5), 8–14.

SCHROEDER, H.W. (2007). Place experience, gestalt, and the human-nature relationship. *Journal of Environmental Psychology* **27**, 293–309.

SCHROEDER, H.W. AND CANNON, W.N. (1983). The esthetic contribution of trees to residential streets in Ohio towns. *Journal of Arboriculture* **9**, 237–243.
SCHROEDER, H.W. AND CANNON, W.N. (1987). Visual quality of residential streets: Both street and yard trees make a difference. *Journal of Arboriculture* **13**, 236–239.
SCHROEDER, H., FLANNIGAN, J. AND COLES, R. (2006). Residents' attitudes toward street trees in the UK and U.S. communities. *Arboriculture and Urban Forestry* **32**, 236–246.
SCHROEDER, H.W. AND RUFFOLO, S.R. (1996). Householder evaluations of street trees in a Chicago suburb. *Journal of Arboriculture* **22**, 35–43.
SOMMER, R., GUENTHER, H. AND BARKER, P.A. (1990). Surveying householder response to street trees. *Landscape Journal* **9**(2), 79–85.
TAKANO, T., NAKAMURA, K. AND WATANABE, M. (2002). Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of Epidemiology and Community Health* **56**, 913–918.
TAYLOR, A.F., KUO, F.E. AND SULLIVAN, W.C. (2001). Coping with ADD: The surprising connection to green play settings. *Environment & Behavior* **33**, 54–77.
TAYLOR, A.F., KUO, F.E. AND SULLIVAN, W.C. (2002). Views of nature and self-discipline: evidence from inner city children. *Journal of Environmental Psychology* **22**, 49–63.
TINSLEY, H.E.A. AND TINSLEY, D.J. (2001). *Older urban park users' and non-users' perceptions and preferences of Lincoln Park, Chicago*. Final report RJVA-23-98-18. USDA Forest Service, North Central Research Station, Evanston, Illinois.
TINSLEY, H.E.A., TINSLEY, D.J. AND CROSKEYS, C.E. (2002). Park usage, social milieu, and psychosocial benefits of park use reported by older urban park users from four ethnic groups. *Leisure Sciences* **24**, 199–218.
TREELINK (2008). *TreeLink's quote source.* TreeLink, Salt Lake City, Utah, USA. [Online] Available at: http://www.treelink.org/linx/Quotesearch.php [Accessed January 2011].
ULRICH, R.S. (1984). View through a window may influence recovery from surgery. *Science* **224**, 420–421.
ULRICH, R.S. AND ADDOMS, D.L. (1981). Psychological and recreational benefits of a residential park. *Journal of Leisure Research* **13**, 43–65.
ULRICH, R.S., SIMONS, R.F., LOSITO, B.D., FIORITO, E., MILES, M.A. AND ZELSON, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology* **11**, 201–230.
WOLF, K. (2005). Business district streetscapes, trees and consumer response. *Journal of Forestry* **103**, 396–400.

# Urban trees and the green infrastructure agenda

## Abstract

Urban trees are an integral and critical part of the Green Infrastructure Agenda. This paper examines their importance by reference to the work of the Trees and Design Action Group (TDAG) and Victoria Business Improvement District (BID). The research undertaken by TDAG and the Victoria BID clearly demonstrates the quantifiable benefits of urban trees in terms of their social, environmental and economic contribution to the Green Infrastructure Agenda. The ongoing research and delivery mechanisms will form the basis for further empirical evidence. The evidence supports urban trees for the multiple benefits they deliver and the cost-effectiveness of investment in both planning and maintaining urban trees. Reductions in public finance mean the Business Improvement Districts could become key vehicles for protecting and planting urban trees for the wider community benefit. Agencies, such as TDAG, have a vital role to play in the Green Infrastructure Agenda.

## Green infrastructure

**Keywords:**

Business Improvement Districts, delivery, green infrastructure, Trees and Design Action Group, urban trees

Green infrastructure (GI) is embedded in national sustainability policy, and its importance is highlighted in several national planning policies, including PPSI (Sustainable Development) PPS9 (Biodiversity and Geodiversity), PPS12 (Local Spatial Planning), PPS25 (Development and Flood Risk) as well as the Consultation Draft PPS 'A Natural and Healthy Environment'.

In particular, PPS12 requires local planning authorities to assess GI requirements. Climate adaptation through measures including GI is also required by the Climate Change Act (2008). Natural England's GI Guidance (Natural England, 2009) reflects this role, and describes GI as a 'life-support system' in terms of its role in adapting urban areas to climate change. It defines GI as:

> *A strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features. It should be designed and managed as a multifunctional resource capable of delivering those ecological services and quality of life benefits required by the communities it serves and needed to underpin sustainability.*

Planning is currently in a state of flux and the future of the PPS documents is uncertain. Consequently, the effects of losing this layer of planning guidance will need to be ascertained. Tree strategies are likely to be a vital component and, ideally, should follow an agreed outline so that they can be readily understood by all practitioners regardless of location within the UK.

## Trees and Design Action Group

The Trees and Design Action Group (TDAG) was formed in early 2007. It is a voluntary organisation consisting of a very diverse group of organisations and individuals with the common vision to protect and enhance urban trees. The group set out a 10-point Action Plan which continues to inform the group's work:

1. **To promote integrated solutions to the urban realm.** Trees can only be protected or planted if the right decisions are made at the right time. Joined-up thinking is needed between government departments, regional, local and transport authorities, and a multi-disciplinary approach is required for planning, design and management. TDAG's aim is to promote greater information exchange and consistency between all the relevant parties concerning urban trees.

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2. **Planning policies and tree strategies.** It is essential that the local planning authorities (policy, development control, enforcement and building control) have in place best practice policy and procedures to ensure that trees of high landscape value are protected and retained and that new landscape plantings are implemented and established to provide tomorrow's landscape. TDAG will work with government and all interested parties to ensure that every local authority in England has access to best practice in these important areas of the planning system. Urban trees are part of the overall urban forest and are the largest elements in green infrastructure. The two are closely linked, but it is important to emphasise issues relating to trees specifically and so TDAG will highlight the importance of local tree strategies being supported by Regional Policy and Local Development Frameworks core strategies. Guidance on urban trees should be firmly underpinned by legislation and managed through statutory requirements and enforcement.

3. **Evidence-based understanding and research.** Understanding is needed with evidence-based research to put the 'blame culture' approach into perspective, e.g. subsidence claims. TDAG will help collate and explain existing research rather than commissioning new research. TDAG will also seek to identify where the gaps are in current research and feedback findings to the research bodies.

4. **Education and public awareness.** TDAG will work to help alter negative perceptions of trees. TDAG will continue to highlight the benefits of urban trees and how they greatly outweigh some negative connotations (e.g. fruit fall, leaf drip). TDAG will also help raise awareness of how trees physically affect the built environment (subsidence, pavement upheaval etc) and how these problems can often be avoided.

5. **Value, funding and revenue.** The quality of our urban trees can affect the overall perception and competitive advantage of the urban environment. Trees can provide measurable economic, environmental, social and health benefits (reduced asthma rates and uplifted property values for example). Trees also have an asset value in their own right and a common system should be established for valuing urban trees. TDAG promotes a benefit analysis approach when making the case for urban trees which can deliver multiple benefits.

6 **Streetscape and the 4-dimensional urban realm.** A dense urban environment (both over and underground) means particular challenges need to be overcome to ensure trees are properly planted and maintained. TDAG will publish guidance on trees in the streetscape to help practitioners overcome some of these challenges.

7. **Trees live more than the 30 year development cycle.** Development cycles are very short (as little as 30 years for some buildings), and developers should be encouraged to include large trees in new developments wherever possible. TDAG will publish practical guidance on how to incorporate large trees into new developments.

8. **Landscape character including density issues.** Increased land values and densities means that trees and open space/urban greening can be neglected by urban planners. Aspirations for green space (and tree) quantity are expressed in various reports, such as those relating to climate change, wellbeing etc. TDAG will help collate existing guidance and best practice to help practitioners identify optimal grey/green ratios in the built environment.

9. **Public realm management and funding for aftercare and maintenance.** Tree management and aftercare is essential to ensure the long-term wellbeing of urban trees. TDAG will provide guidance to practitioners on how to approach long-term urban tree management.

10. **Townscape.** Trees can often provide continuity and maintain area identity even if buildings change. TDAG will publish guidance on trees and townscapes as part of its guidance on street trees and trees in the private realm which influence the streetscape. The guide will include reference to historic townscapes as well as contemporary planting to allow integration with the planning process at the regional and local policy level.

In a recent article (Kelly, 2010) the critical issues for trees in the townscape were explored under the following headings.

## The contribution of urban trees

There is a certain sensation produced when walking in the cool of a tree-lined street on a hot summer day with the sun dappling through the leaves that is very appealing. With all the challenges we face in the urban realm – environmental, social and economic – trees, which deliver multiple benefits, are emerging as our greatest allies. Unfortunately, there is a tendency to take trees for granted and in many parts of our towns and cities our tree cover, especially of large species trees, is a legacy from previous generations. Clearly, we need to act now for future generations.

## What is the case for urban trees?

Climate change with the likelihood of increased temperatures creating what is known as the urban heat island effect; heavier rainfall events and flash flooding; the loss of biodiversity; poor urban air quality – the list of environmental challenges is growing. Completed and emerging research has identified the beneficial role that trees can contribute to improving these conditions (Ennos, 2010). Street trees in particular can also create the structural links for our urban green grids which can help to improve urban wildlife corridors. Tubbs (1942) pre-empted the green grid concept when he proposed integrating the urban and rural landscapes with green 'links' or fingers stretching from the surrounding countryside into urban areas.

The social benefits of trees include reducing stress, encouraging walking and exercise thus improving health, reducing crime and the fear of crime (Kuo and Sullivan, 2001) and improving road safety by reducing traffic speeds. Trees also contribute to local identity.

It is interesting to note that in Britain few streets had trees planted in them until the early 1870s when almost all new residential streets were lined with trees. Dyos (1961) explains that the choice of tree related to the social class predominating in a particular neighbourhood. So, plane trees and horse chestnuts were planted in wide avenues with large houses for the upper classes; limes, laburnums and acacias were provided for the middle incomes and 'unadorned macadam for the wage-earners'.

Today, it is important that the balance of tree cover in the cities is remedied so that areas previously ignored are given the advantages that trees can bring. We need to talk in terms of the 'urban forest' – banish thoughts of Brothers Grimm and focus instead on every new tree planted adding to the overall urban tree population!

The economic case for trees has been promoted by the US Forest Service with the introduction of STRATUM (Street Tree Resource Analysis Tool for Urban Forest Managers). The most significant information to date comes from cities such as New York which have calculated that $1 per annum invested in trees can return $5 per annum in quantifiable benefits including increases in property value; aiding stormwater management by reducing the peak-flow rate; energy saving for buildings and improving air quality. A test case using i-Tree Eco has been carried out in the UK by Hi-line Consultancy working with Torbay Council and the Forest Research arm of the Forestry Commission (Rogers *et al*., 2011).

It is hoped that this process will be repeated throughout the UK and that, in due course, further inputs can identify additional benefits such as health and wellbeing benefits, biodiversity benefits and others. Clearly, the ability to apply a benefit analysis for trees will be a useful tool for all working with urban trees.

## What are the barriers to planting urban trees?

The case for trees is compelling but, unfortunately, there is a gap between the desire to plant more trees and the ability to do so. One of the critical barriers is the complexity of the urban infrastructure and the competition for space below ground. Ideally, trees should be planted for the long term so that they can grow to maturity and deliver their benefits. This means that they need soil volume to grow in. To make this possible it is important to stress another requirement and that is the need for integrated, joined-up thinking and planning so that the use of space both below and above ground is properly thought through and coordinated.

Even though we are in a time of economic austerity, it is still important to plan for the future and investment to rationalise underground services to include the planting of trees as part of an integrated approach would be a price worth paying (NYC, 2005)

It is also important to be aware of sub-soil conditions. Many of our historic urban areas are located in river valleys because that was the main means of communication and trade. This can mean that the ground conditions, as in large parts of London for example, are shrinkable clay soils. Subsidence must not be used as a potential threat and it should not be assumed that subsidence is always caused by trees (LTOA, 2007). However, Victorian terraces with shallow foundations on shrinkable clay sub-soils could be vulnerable to subsidence in any event if the climatic conditions are right and trees can, in some situations, exacerbate these problems. However, the way forward is not to make assumptions about trees sizes, species and distances to low rise buildings but to seek expert advice, take a risk assessment approach and ensure that the trees that are planted can be allowed to grow to maturity with the necessary ongoing maintenance and management (BRE, 1993)

## Where are the opportunities to plant urban trees in the townscape?

Front gardens sometimes provide the only opportunity for trees and urban greening and the Royal Horticultural Society (RHS) is among others campaigning to protect gardens. Gardens, both front and back, are key components for providing green lungs and opportunities for sustainable rainwater drainage to reduce flash flooding. It is hoped that these resources will be protected and not paved over to provide off-street parking.

There are times when roadways are unnecessarily wide and, by narrowing the carriageway, road space can be won back for pedestrians and trees. The City of London has so far regained areas equal to more than six football pitches by reducing carriageways. In Islington in the EC1 New Deal for Communities area to the east of Farringdon Road, cul-de-sacs have been converted into pocket parks for residents. Again, working together can seek out these opportunities.

With changes to public finances and greater emphasis on local actions, it could be that Business Improvement Districts (BIDS) can provide a mechanism for local change. This is the case with several BIDS in London such as Better Bankside and the Victoria BID.

## Victoria Business Improvement District

Following a successful ballot and a positive outcome to establish a Business Improvement District (BID) in Victoria, this will provide a platform for businesses to work together to improve and enhance the urban context of Victoria. Guided by businesses and organisations based within the SW1 area, the Victoria BID team will help shape Victoria's future development. A full programme of initiatives is being established with services and events to deliver during the first term of the BID. These will be further complemented by new proposals for regeneration of the area that will help reposition and strengthen Victoria's offer as a central business district over the next decade.

As the collective voice of local businesses, both large and small and across all sectors, Victoria BID is now underway with a range of activities. Drawing on Victoria's rich and diverse cultural mix, delivering services and opportunities to businesses and organisations, helping to make Victoria not only a better place to work and play but to enhance the SW1 area as a primary destination for visitors to London and as a location with everything needed to encourage growth of the local economy.

The Victoria BID identified a number of key strategic themes to shape regeneration, of which the 'Clean and Green' theme offers an opportunity to redress the current deficiencies in green infrastructure in the area. GI can deliver numerous functions or services, and provide significant contributions to social, environmental and economic agendas. The key functions which GI can deliver in the Victoria BID include:

- **Economic benefits** including flood management and alleviation to reduce the risk of flooding and increasing the draw of the area to local visitors and tourists as well as enhancing property values.

- **Environmental benefits** including climate control through air cooling in summer months, provision of habitats and migration routes for wildlife, reduction of surface water flooding and filtration of pollutants.

- **Social and cultural benefits** including outdoor areas for recreation, transport, education and relaxation.

## Research study

In August 2010, the Clean and Green Steering Group commissioned a research study in the form of an Audit of Green Infrastructure in the Victoria BID area in Central London. 'Clean and Green' is one of the five key themes defined by the Victoria BID. The Steering Group for the audit comprised representatives of five organisations which sit on the Clean and Green panel: Natural England; the Greater London Authority (GLA); the London Biodiversity Partnership; Capita Symonds (formerly Capita Lovejoy) and the Victoria BID.

The scope of the research study undertaken by Land Use Consultants (LUC, 2010) was as follows:

- An audit of green infrastructure within the public and private realm, including the following:
  - terrestrial (ground level) GI resource and opportunities;
  - green and flat roofs;
  - trees.
- Opportunities for enhancement and creation to improve the GI resource.
- Guidance on the potential and feasibility of delivering GI, urban flood management features and green roofs in the study area.
- Accurate GIS mapping, setting out the location of existing GI, and the locations where tree cover enhancement opportunities exist.

Information on trees was provided from two data sources:

- Public realm trees from Westminster City Council produced by RA software using their product EzyTreev.

- Public and private realm trees data (ProximiTree) derived from GeoPerspectives Aerial Photography and supplied by Bluesky International Ltd.

## Trees and their canopy cover (private and public realm)

For this part of the assessment, trees within the BID area have been isolated from both the ProximiTREE database and the public realm database for comparison.

Within the core area, there are 177 trees in the ProximiTREE database which includes both public and private realm trees. There are 70 trees in the public realm database. By implication, around 100 trees in the core would be expected to be in the private realm. A close inspection of the tree datasets in GIS reveals that it is more likely that 126 of the 177 trees in the ProximiTREE database have no equivalent tree in the public realm tree database. It is therefore assumed that these will most likely be 'private trees'. Comparing the remaining 51 trees in ProximiTREE (which are assumed to be 'public trees' due to their proximity to a tree with the public realm database), there are fewer 'public' trees in ProximiTREE. Of the ProximiTREE trees which have an 'equivalent' tree in the public realm database (based on proximity), there can be up to 10 m positional difference between tree trunks and some variation between canopy size. As no dataset showing 'public' and 'private' land is available at this stage, the categorisation of ProximiTREE trees into public and private is speculative.

Trees in ProximiTREE have been categorised into public and private using the method described above. In order to calculate canopy cover, it has been necessary to eliminate overlaps where trees are in very close proximity.

## Delivery

There are numerous and wide-ranging opportunities to deliver green infrastructure enhancements across the Victoria BID. The BID Partnership is adopting a coordinated approach to delivering these opportunities.

Delivery of the green infrastructure features will be coordinated by the BID but may be implemented by partner organisations. The BID had a designated funding pot of investment under its Clean and Green theme, and some of the enhancements within the public and private realm will be funded in this way. Where enhancements will deliver direct benefits to specific companies, it may be appropriate for the BID to negotiate for the enhancement to be partly or wholly funded by these business partners. This will maximize the enhancement that can be delivered with the allocated Clean and Green funding.

Due to the dense urban character of the study area, with the extent of underground infrastructure, and other constraints that such built up areas place on the ability of trees to establish, opportunities to plant new trees are limited. Those sites where there is scope to plant new trees include the existing green spaces of Lower and Upper Grosvenor Gardens, and Christchurch Gardens, as well as some streets, including Lower Grosvenor Place, a wide avenue where there are very few street trees, and the green space adjacent to the Queens Gallery.

Other tree planting opportunities include Westminster Cathedral Piazza, although any planting would need to be sensitively designed so as to be suitable to the setting of this listed building, Belgravia Police Station, where small trees could be introduced, and Royal Mews, part of the Buckingham Palace site with a large car park around with which there is some potential for tree planting. Detailed costing and programmes have been prepared as part of the delivery strategy.

Since completion of the Green Infrastructure Audit of Victoria, we have been finalising a bid to the GLA's Drain London fund, which seeks to reduce or mitigate surface water flood risk in the area.

## Data accuracy: tree data

Two datasets, Westminster Council's public realm tree data and an alternative tree dataset 'ProximiTREE', were compared for data accuracy. The public realm tree data is a detailed GIS dataset holding information on a number of attributes for each tree (described below). ProximiTREE data is also held in GIS and has locations of trees in both the public and private realm. The dataset has two components:

- A point location for the trunk of the tree with information on base height, crown height and actual tree height.
- A polygon representing the crown width.

As part of the ground-truthing exercise, the accuracy of the tree locations within ProximiTREE was checked in the field. Each auditor had field maps showing both tree datasets (and the ProximiTREE canopies). On the whole, the locations were deemed to be accurate. In a couple of cases, new trees were identified or it was noted that trees had been removed. Access to private realm trees was limited, and unfortunately aerial photography was not available for use in GIS. This is explored in more detail later in this section.

## Private realm tree data

Ground-truthing was undertaken to determine the accuracy of the private realm tree data. Location and number of trees at the following locations were reviewed:

- Cardinal Place
- Palace Street
- Castle Lane

Data was found to be accurate. There were a few young/ newly planted trees in private gardens off Castle Lane, and in the private grounds off Palace Street (opposite Victoria Hotel).

## Other data

During the ground-truthing exercise, it was established that some of the Ordnance Survey MasterMap boundaries were out of date. This is particularly the case for Lower Grosvenor Gardens, which has a different layout to that mapped by the Ordnance Survey.

## Public realm tree assessment

The public realm tree database for GIS dataset has a point location for each public realm tree. For each tree in the database there is information on:

- Location
- Species
- Grid Reference
- Height (m)
- Canopy spread (diameter in m)
- Age

In addition to the data on existing trees, the dataset also contained information on 'vacant tree pits' and 'suitable for new tree location' (Table 1). It is unclear from the GIS data on what basis these 'new tree locations' have been identified. For the purposes of this analysis, the trees were broken down by location into threes that are:

- within the core areas (Victoria BID zone);
- within the outer zone (within 200 m of the Victoria BID area).

**Table 1** Number of trees by broad location and category.

| Category | Core zone | Outer zone | Total |
|---|---|---|---|
| Existing tree | 70 | 285 | 355 |
| Suitable for new tree location | 3 | 10 | 13 |
| Vacant tree pit | 0 | 3 | 3 |
| **TOTAL** | **73** | **298** | **371** |

## Detailed analysis of dataset

The core area contains 20% of the total trees in the wider study area and the remaining 80% are within the outer area. There were 37 species within the wider study area.

Figure 1 (see page 172) shows those trees within the public realm focused on the core and outer areas and Figure 2 (see page 173) and Figure 3 show the distribution of public realm trees by species within the core area.

**Figure 3** Public realm tree species in the core area.

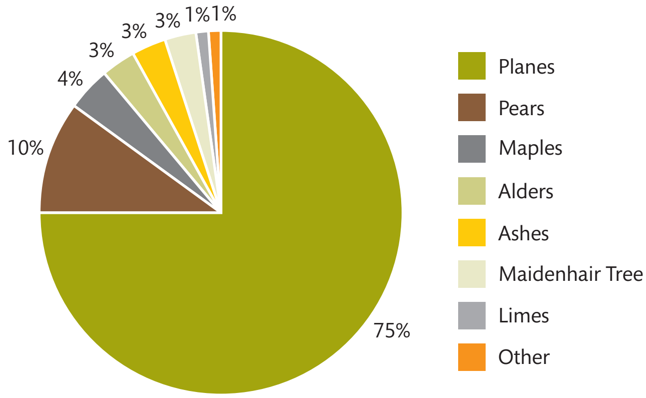



Table 2 shows the breakdown of existing trees by location and age. The core and outer zones have a very small proportion of new trees and no overmature trees. Overall, the majority of the trees in the wider study area are categorised as young, followed closely by mature trees.

**Table 2** Breakdown of existing trees by age category.

| Category | Core zone | Outer zone | Total |
|---|---|---|---|
| New tree | 3 | 14 | 17 |
| Young tree | 24 | 159 | 183 |
| Mature tree | 43 | 112 | 155 |
| Overmature | | | 0 |
| **TOTAL** | **70** | **285** | **355** |

Figure 1 Public realm trees.

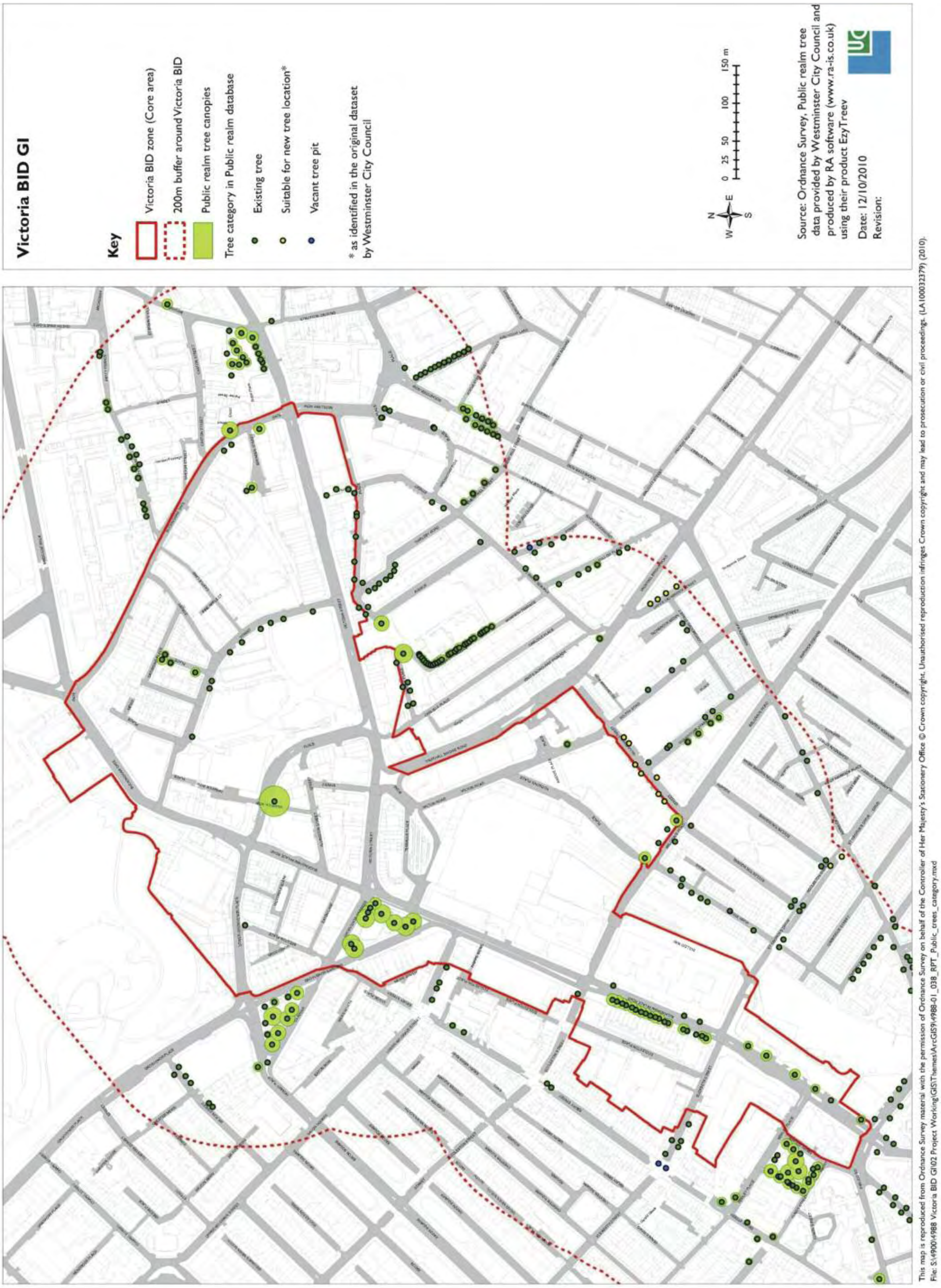


Figure 2 Public realm trees by species.

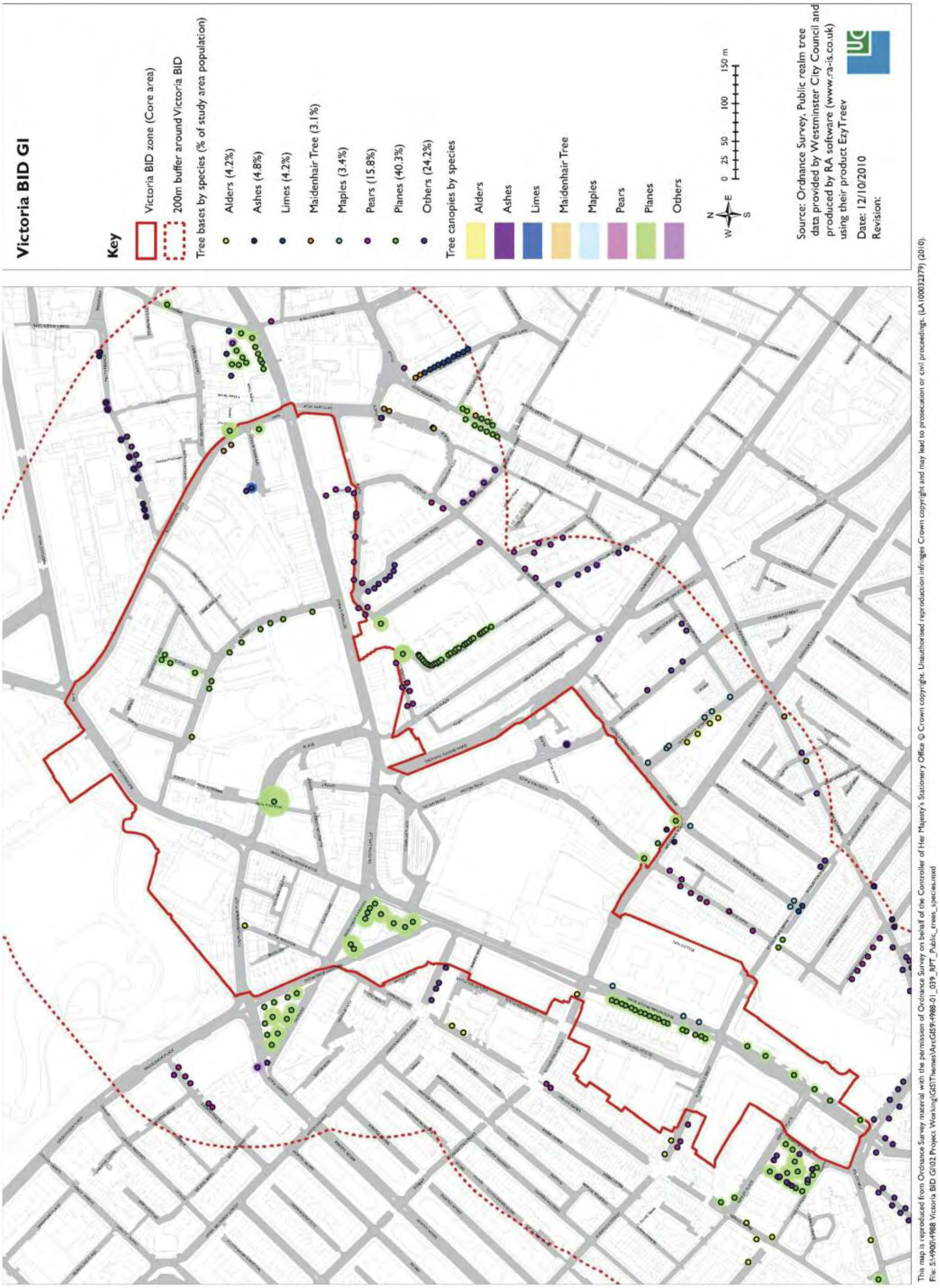
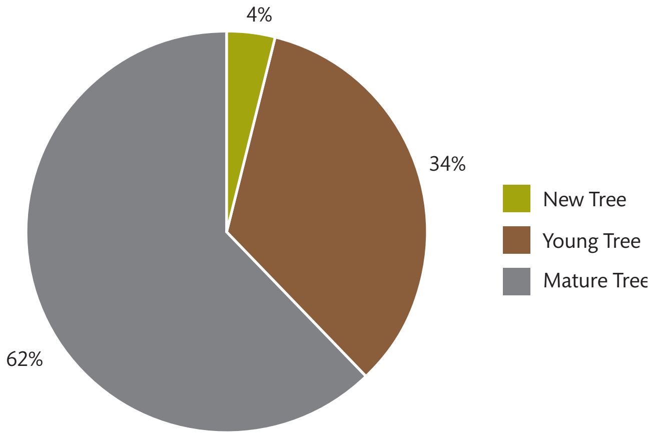


Figure 4 illustrates the breakdown of tree ages within the core area. The majority of trees in the core area are mature. These are mapped in Figure 5 (see page 176), which shows the public realm trees by age.

**Figure 4** Trees by age in the core area.




## Tree canopy cover in the core area

Canopy cover of trees in the Core BID area was also explored. Figure 6 (see page 177) shows the data from both databases for the core area. Trees in ProximiTREE have been categorised into public and private using the method described above. In order to calculate canopy cover, it has been necessary to eliminate overlaps where trees are in very close proximity. The results are summarised in Table 3. The sites visited in the audit are listed in Table 4.

### Trees

A large number of the existing trees in Victoria's public realm are mature (over half of total population in core area), and therefore some succession planting should be planned. There is currently 16 197 $m^2$ of canopy in the core area, or 15 225 $m^2$ if overlapping tree canopies are discounted. The majority of trees in the core area have a canopy size of 5–15 m, with larger tree canopies contributing more towards alleviating urban heat island effects.

The Westminster *Trees and the Public Realm* SPD recommends generally using the tree species with the largest canopy a site can accommodate, in light of its potential size when fully grown (Westminster City Council, 2009). Native species may be considered to be a better choice for biodiversity potential. However, there is a limited range of native species which are suitable for an area such as Victoria, which suffers from air pollution (Johnston *et al*., 2011). It is also important, to consider the predicted effects of climate change, and tree species which are suitable for warmer climates similar to that predicted for London in the next 20–50 years.

Tree species with large but open canopies are likely to deliver the greatest benefits both in terms of aesthetic and amenity value to spaces as well as alleviating the urban heat island effect and contributing to slowing stormwater run-off during heavy downpours.

As described above opportunities for new tree planting are limited but, in addition to the sites described, there is also potential to incorporate additional street tree planting alongside any changes to pavement alignment of new central strips as a part of future transport infrastructure improvements. These species would need to be suitably tolerant of pollution, drought and waterlogging.

## Next steps

There are numerous and wide-ranging opportunities to delivery green infrastructure enhancements across the Victoria BID. The BID Partnership is adopting a coordinated approach to delivering these opportunities and the following paragraphs provide some recommendations on the next steps.

**Table 3** Comparison of ProximiTREE and public realm tree data.

| Database | Number of trees in core area | Total area of canopy (sq m) without removing canopy overlaps | Total area of canopy (sq m) after canopy overlaps have been removed | % land area covered by tree canopy |
|---|---|---|---|---|
| Public realm trees | 70 | 9794 | 8034 | 1.95 |
| ProximiTREE | 177 | 16 197 | 15 225 | 3.7 |
| Assumed public | 51 | 8419 | 7829 | 1.9 |
| Assumed private | 126 | 7777 | 7396 | 1.8 |

Table 4 Sites visited during the audit.

| Site ID | Name/Location | Size (sq m) | Existing GI asset for enhancement | Potential GI asset |
|---|---|---|---|---|
| 1 | Lower Grosvenor Gardens | 2878 | ✓ | |
| 2 | Grosvenor Gardens Mews (two small areas opposite Lygon Place) | 41 | ✓ | |
| 3 | Outside Belgravia Court on Ebury Street | 247 | ✓ | |
| 4 | Wall on east of Bulleid Way | 192 | | ✓ |
| 5 | Area on corner of Bulleid Way/Elizabeth Street | 135 | | ✓ |
| 6 | Outside entrance to National Audit Office | 77 | | ✓ |
| 7 | Belgravia Police Station | 156 | ✓ | |
| 8 | Fountain Court Pimlico/Buckingham Palace Road | 214 | ✓ | |
| 9 | Cundy Street Flats | 1592 | ✓ | |
| 10 | Corner of Ebury and Elizabeth Streets | 132 | | ✓ |
| 11 | Beeston Place, opposite Goring Hotel | 139 | ✓ | |
| 12 | Lower Grosvenor Place – south side | 123 | | ✓ |
| 13 | Royal Mews | 3229 | | ✓ |
| 14 | Green space by entrance to Queens Gallery, Buckingham Palace Gate | 197 | ✓ | |
| 15 | Paved area outside Queens Gallery, Buckingham Palace Gate | 31 | | ✓ |
| 16 | Either side of Buckingham Palace Gate, North | 294 | | ✓ |
| 17 | Warwick Row – off Bressenden Place | 77 | | ✓ |
| 18 | In front of Eland House, Bressenden Place | 74 | | ✓ |
| 19 | In front of Portland House, Bressenden Place | 37 | | ✓ |
| 20 | Clock Tower | 383 | | ✓ |
| 21 | Victoria Street/Carlisle Place (corner) | 75 | ✓ | |
| 22 | Westminster Cathedral Piazza | 2115 | | ✓ |
| 23 | Cardinal Walk | 835 | ✓ | |
| 24 | Victoria Street, covered arcade | 808 | | ✓ |
| 25 | Wilcox Place | 390 | | ✓ |
| 26 | 57 Buckingham Gate | 39 | | ✓ |
| 27 | Vandon Passage | 196 | | ✓ |
| 28 | Building Facade, rear of Westminster Kingsway College | 85 | | ✓ |
| 29 | Traffic island on Victoria Street | 17 | | ✓ |
| 30 | Corner of Brewers Green and Caxton Street | 29 | | ✓ |
| 31 | Large paved area – Brewers Green | 188 | | ✓ |
| 32 | Christchurch Gardens | 1701 | ✓ | |
| 33 | Pineapple Court – outside Colonies pub | 136 | | ✓ |
| 34 | Paved area north of Lower Grosvenor Gardens | 62 | | ✓ |
| 35 | Near Seaforth Place and Spenser Street | 843 | | ✓ |
| 36 | Outside St James Park Station | 68 | | ✓ |
| 37 | Raised beds on Buckingham Palace Gate | 171 | ✓ | |
| 38 | Westminster City School | 6151 | ✓ | |
| 39 | Planted beds either side of Fountain Square | 655 | ✓ | |
| 40 | Ashley Gardens | 1473 | ✗ | |
| 41 | Victoria Station, Bridge Place | 490 | | ✓ |
| 42 | Upper Grosvenor Gardens | 0 | ✓ | |
| 43 | Wilton Road/Hudson's Place | 280 | | ✓ |
| 44 | Apollo Victoria Theatre | 69 | | ✓ |
| 45 | Wilton Road building facade | 19 | | ✓ |
| 46 | Vauxhall Bridge Road at Park Plaza Victoria Hotel | 92 | | ✓ |
| 47 | Vauxhall Bridge Road, pedestrian crossing/island | 266 | | ✓ |
| 48 | Howick Place, triangular planter | 15 | ✓ | |
| 49 | Howick Street, pavement | 66 | | ✓ |
| 50 | Butler Place | 334 | | ✓ |
| 51 | Vandan Street | 130 | | ✓ |
| 52 | Petit France Street, leftover space | 12 | | ✓ |
| 53 | Petit France Street, at Palmer Street | 139 | | ✓ |
| 54 | Palmer Street car park | 501 | | ✓ |
| 55 | Palmer Street, Asticus Building | 165 | | ✓ |

Figure 5 Public realm trees by age.

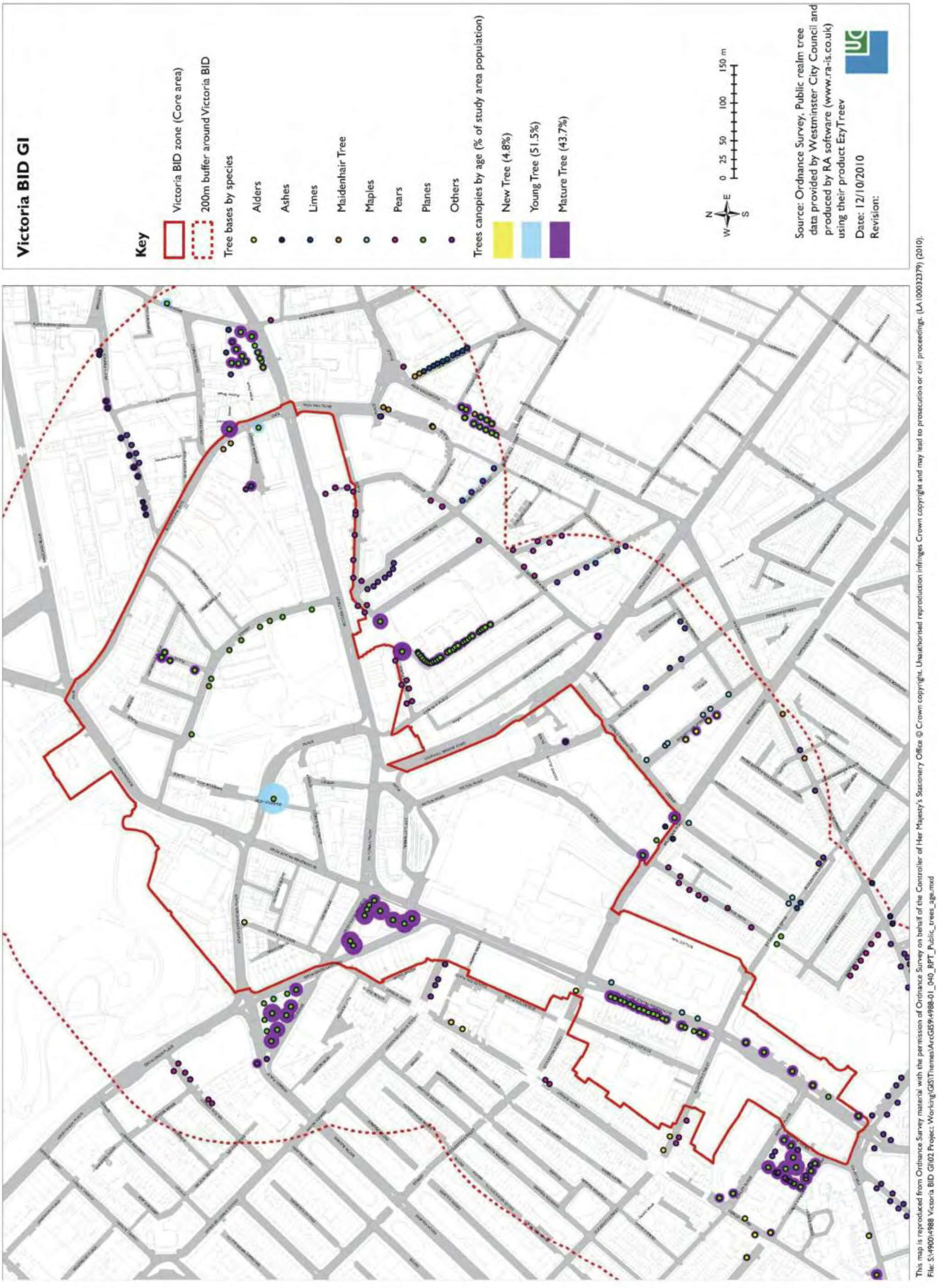
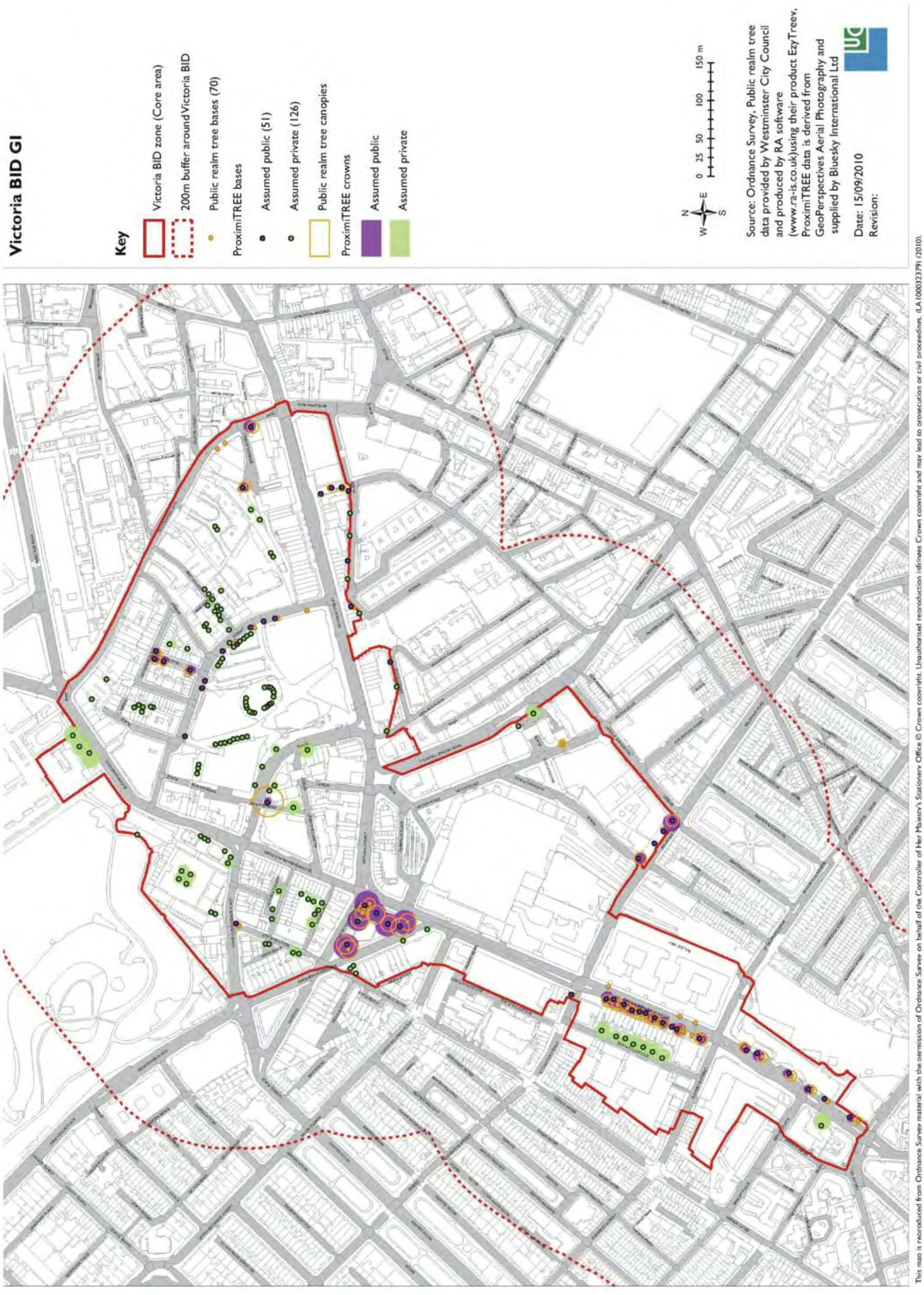


Figure 6 Comparison of ProximiTree and public realm tree data.



## Consultation

Consultation with landowners, local groups and community representatives will be essential to the effective delivery and long-term maintenance of the green infrastructure features. We suggest that a short period of consultation with the BID Partners should take place. Consultation will achieve the following:

- Allow interested parties to comment on opportunities that have been identified on their property, or related to sites and infrastructure in which they have an interest.
- Ensure that an opportunity is provided to raise any concerns about the proposals, identify constraints, and comment on potential design.
- Enable the BID to refine its priorities and deliver GI enhancements with the support of the BID and the wider business and resident communities.

We suggest that consultation with Westminster Council should be undertaken as a priority, as many of the opportunities identified are within the public realm and public open spaces, the management of which is the Council's responsibility.

## Additional surveys

For some of the opportunities identified, further survey work will be required to ensure that the site or building is suitable for the proposed feature. This is particularly true of the green roof opportunities, and all buildings will require a structural survey to ensure the building can safely accommodate the additional weight that the installation of a green roof generates.

For some terrestrial proposals, surveys should be undertaken to identify the presence of soil or substrate under the existing hard surface, as well as any underground infrastructure. This will help to prioritise opportunities further, as some may be more easily delivered due to the presence of appropriate soil/substrate, and absence of any underground infrastructure.

## Design

Many of the smaller terrestrial proposals can be delivered without the need for design input from specialists. For the larger features, however, design advice should be sought.

Appropriate types of design guidance include:

- Planting advice at existing parks and gardens, including species which are beneficial to wildlife. The Council may be able to provide this expertise in-house.
- Horticultural expertise will be important for most features, in order to ensure that an appropriate suite of species is identified for the conditions (e.g. flood resistant and pollution tolerant in rain gardens, hardy plants for wind tunnels or areas with heavy footfall).
- Townscape assessment and design plans for new features; for example at Cathedral Piazza.

Independent green roof consultants (as opposed to contractors and suppliers) should be consulted prior to installing such features, as they can advise on the creation and design based on the roof style and a range of environmental factors.

For the larger opportunities, such as large green roofs and creation of new green spaces, it is possible that planning permission may be required.

# Delivery

## BID partners

Delivery of the green infrastructure features will be coordinated by the BID, but may be implemented by partner organisations. The BID has a designated funding pot for investment under its Clean and Green theme, and some of the enhancements within the public and private realm will be funded in this way. There may also be external funding initiatives relating to the various functions that the GI opportunities would deliver.

Where enhancements will deliver direct benefits to specific companies, it may be appropriate for the BID to negotiate for the enhancement to be partly or wholly funded by these business partners. This will maximise the enhancements that can be delivered with the allocated Clean and Green funding.

## New developments

There is potential to deliver GI features within new development as the Victoria BID is currently undergoing significant change. The BID should work with Westminster Council as the planning authority, and partner organisations who are statutory consultees, such as Natural England and the Greater London Authority, to negotiate the inclusion of green features within new developments. An exemplar of this approach can be seen at Cardinal Place, where the green roof garden is very popular with office workers and local people. The new development on the site of Seymour House on Victoria Street will also incorporate a green wall as a result of planning negotiation.

Westminster Council is also currently developing its Core Strategy and sustainable design guidance for future construction in the City, and there may be potential for the BID to comment on the scope and content of this design guidance.

## Maintenance

Maintenance of the new GI features will be essential to maintain provision of functions such as alleviation of surface water flooding, and their appearance. The options for maintenance need to be considered by the BID at the outset, as this is likely to influence prioritisation of opportunities to be delivered. There should be a maintenance plan in place prior to delivery, including which partners will be responsible for maintaining the features. As many of the identified opportunities are within the public realm, Westminster Council will have a key role to play in agreeing where responsibility for management and maintenance will lie. There may be a need to consider creating an independent body which will oversee GI maintenance, such as a GI trust.

## Monitoring

A monitoring approach should be agreed for the delivery of the identified opportunities. This should monitor:

- the delivery of the GI features and the extent of green features across the Victoria BID;
- the quality of the GI features, and maintenance.

Monitoring will help inform priorities for investment of the Clean and Green funding over the five year BID period, and will provide quantified information to enable the success and outputs of the BID investment to be measured. The planned investment in urban green infrastructure by the Victoria BID is an innovative approach to addressing green space deficiency and opportunities for enhancement of dense urban areas. Monitoring the outputs will support the promotion of this innovative approach as an inspiring example of retrofitting GI into the inner city environment.

# Conclusions

The evidence supports urban trees for the multiple benefits which they deliver and the cost-effectiveness of investment in both planting and maintaining urban trees.

There are some barriers to protecting existing trees and planting additional trees to increase canopy cover and the overall extent of the urban forest:

- Changes are being made to planning strategies, policies and delivery. It is vital that tree strategies are developed for all local authorities and are embedded as policy within the Local Development Frameworks as they appear to be the one planning policy that is intended to remain in place to inform and guide local decision making.
- A sustainable integrated infrastructure approach is long overdue in most cities, certainly in England. There needs to be greater control over the statutory rights of utilities, NJUG Volume 4 (the NJUG guidelines for the Planning, Installation and Maintenance of Utility Apparatus in Proximity to Trees (Issue 2) Operatives Handbook) needs to be mandatory not voluntary and guidance such as the *High performance infrastructure guidelines* produced in New York City in 2005 provide a clear road map for moving forward effectively in this area (NYC, 2005).
- Benefit analysis for trees needs to be common practice so that each local authority has a clear picture of the quantifiable benefits that the trees can deliver within its boundaries, on both public and private land. This analysis will also be helpful for landowners with responsibility for trees on their land as the benefits will justify the costs of protecting, planting and maintaining urban trees.
- New planting must take account of a more sophisticated approach to species selection so that trees can face future challenges and deliver maximum benefits. The approach to tree planting must take account of the quality of the tree stock from the nursery to maturity – a longer time span than the five years usually assigned to tree establishment.
- Reductions in public finance mean that Business Improvement Districts could become key vehicles for protecting and planting urban trees for the wider community benefit.

# References


BRE (1993). *BRE Digest 240 Part 1: Low Rise Buildings on Shrinkable Clay Soils*. Institution of Structural Engineers (2000) IStructE Guide: Subsidence of Low Rise Buildings.

DYOS, H.J. (1961). *Victorian suburb: A Study of the Growth of Camberwell.* Leicester University Press.

ENNOS, R. (2010). Urban cool. *Physics World* **23**(8), 22–25.

JOHNSTON, M., NAIL, S. AND JAMES, S. (2012). 'Natives versus aliens': the relevance of the debate to urban forest management in Britain. *In:* Johnston, M. and Percival, G. (eds.) *Trees, People and the Built Environment: Proceedings of the Urban Trees Research Conference, 13–14 April 2011*. The Forestry Commission, Edinburgh, pp. 181–191.

KELLY, M. (2010). Keeping trees in the townscape. *Green Places*, Winter edition **70**, 36–37.

KUO, F.E. AND SULLIVAN, W.C. (2001). Environment and crime in the inner city – Does vegetation reduce crime? *Environment and Behaviour* **33**(3), 343–367.

LTOA (2007). *A Risk Limitation Strategy for Tree Root Claims*. 3rd edition. London Tree Officers Association.

LUC (2010). *Victoria Green Infrastructure Audit*. Land Use Consultants. [Online] Available at: http://www.insw1.com /Branches/Victoria%20BID/inSW1/Files/Documents/Press /Releases/VBID_GI_Report_2010.pdf.

NATURAL ENGLAND (2009). *Green infrastructure guidance*. Natural England, Sheffield.

NYC (2005). *High performance infrastructure guidelines – best practices for the public right-of-way*. New York City Department of Design and Construction and Design Trust for Public Space.

ROGERS, K., HANSFORD, D., SUNDERLAND, T., BRUNT, A. AND COISH, N. (2012). Measuring the ecosystem services of Torbay's trees: the i-Tree Eco pilot project. *In:* Johnston, M. and Percival, G. (eds.) *Trees, People and the Built Environment: Proceedings of the Urban Trees Research Conference, 13–14 April 2011*. The Forestry Commission, Edinburgh, pp. 18–28.

TUBBS, R. (1942). *Living in Cities*. Penguin Books Ltd, London.

WESTMINSTER CITY COUNCIL (2009). *Trees and the Public Realm*. (Draft) Supplementary Planning Document. Westminster City Council.

# 'Natives versus aliens': the relevance of the debate to urban forest management in Britain

## Abstract

Since the 1970s, a debate has flourished among landscape professionals and others regarding the relative benefits of planting native or non-native trees in British towns and cities. It has led to some professionals advocating a 'natives only' or 'natives are best' approach to the selection of trees for urban areas. This initially prompted much debate and significant opposition from many other professionals who considered such an approach to be inappropriate. However, these ideas have recently resurfaced in the context of promoting biodiversity in urban areas.

This paper examines the relevance of the 'natives versus aliens' debate to urban forest management in Britain. It investigates a range of factors that can influence the selection of urban trees and, using the findings of some recent research, it explores how native species meet these requirements. In the light of this research it is clear that any automatic preference for native trees when planting in urban areas cannot be justified. We need a far more balanced and sustainable approach to urban tree selection that is based firmly on science.

Recent research has also shown that we need much more specific knowledge to adequately select trees for urban areas to deliver a wide range of environmental, economic and social benefits. This will contribute to improving the welfare of urban residents in what is essentially a human habitat, not a natural one. Lastly, the paper suggests signposts for the future development of this debate, taking into account the complex, wide-ranging factors which need to be considered when selecting appropriate species for British towns and cities.

## Introduction to the 'natives versus aliens' debate

While most people recognise the broad meaning of the concept of 'native', finding agreement on the detail is not easy (Webb, 1985). However, native species are generally regarded as those species which naturally colonised Britain after the retreat of the last Ice Age and before the creation of the English Channel, which ended the land bridge between Britain and continental Europe (Mitchell, 1981; Brown, 1997). Therefore, non-native species are those which were introduced into Britain, either intentionally or unintentionally, after this time. This 'accident of history' ensured a very limited period of about 4000 years for this natural colonisation and has resulted in a particularly sparse native British tree flora of little more than 30 species.

It is difficult to establish the precise origins of the debate about the relative benefits of planting native or non-native trees in Britain and their value in the landscape. However, reference to this topic can be found in literature going back hundreds of years (Gilpin, 1794). In the latter part of the 20th century, the debate has come to preoccupy many landscape professionals and conservationists with seemingly endless exchanges between those advocating 'natives only' or 'natives are best' policies and those who disagree. For the advocates of the former approach this has resulted in a widespread conservation ethic that can be rephrased as 'Native is Good, Alien is Bad' (Fenton, 1986).

Kendle and Rose (2000) present the 'five common arguments' concerning the importance of native plants and the dangers of introduced aliens or exotic species. They examine each of these claims in detail and highlight some of the generalisations and misconceptions used to support them. In their view, the subject is far more complex than these popular and often

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emotive views suggest. They conclude that in a complex environment superimposed on equally complex human history, culture, values and aspirations, it is impossible to characterise one group of plants as 'superior' to others. This is especially true when the classification system is as nebulous and value-laden as our definitions of 'native'.

The United Nations' International Year of Biodiversity held in 2010 intensified the debate on this topic and also served to encourage those wishing to promote a 'natives only' agenda. As well as preoccupying practitioners and academics, it also gained popular media attention and thus influenced public attitudes. Unfortunately, the media content has often been misinformed and overtly biased towards native species. A recent example appeared in an article from the British *Daily Mail* entitled 'The new knotweeds', based on a report published by the charity Plantlife (Thomas, 2010). Readers are given a 'warning over more alien plants set to wreak havoc' (Derbyshire, 2011). Four of the six plants featured as potentially invasive are fairly common trees, established in Britain for many decades, particularly in urban areas. While there may be difficulties with these species in some individual locations, they could hardly be described as the 'new knotweeds' (*Fallopia* spp.). However, the confusion between 'exotic', 'naturalised' and 'invasive' plants persists, not only in the popular media but also in academic work (Richardson *et al.*, 2000). Furthermore, in the vocabulary used to talk about exotic species generally, words abound which conjure up fear. Likewise, words used to describe action against the unwelcome plants often smack of military action (e.g. Krajik, 2005; Marris, 2005).

A call for 'natives only' in landscape planting has often been associated with nationalistic sentiments (Sommer, 2003). While this can be an understandable reflection of national identity and pride, it can also be used to promote political or xenophobic views. At the political level, this raises questions as to the definition of 'native' in spatial terms. For example, to refer to a species as being 'native' to Northern Ireland (Browne, 1996) ignores the geographic entity of the island of Ireland in favour of a recent and purely political boundary that has no relevance to plant distribution. On a more disturbing level, emotive talk about promoting 'natives only' and 'eradicating alien species' can have a damaging impact on community landscape initiatives in a multicultural society (Johnston and Shimada, 2004).

Another reason to avoid being dogmatic is because research can reclassify plants. Many people are still unaware that the 'native' English elm (*Ulmus procera*), the main victim of Dutch Elm Disease, is now known to have been introduced by the Romans (Gil *et al.*, 2004). In the 1980s, there was an academic debate about whether sycamore (*Acer pseudoplatanus*) was actually a native tree (Denne, 1987; Harris, 1987). To the relief of many conservationists who have a well-known dislike of this tree, it now appears this is not the case.

Loss of biodiversity needs to be addressed and sound scientific knowledge has an invaluable role in achieving this. However, in pursuing this, it is important to realise that at least part of the 'natives versus aliens' debate is an emotional one (which does not invalidate it) rather than a scientific one (Fenton, 1986). Furthermore, those with a predisposition to always favour 'native' species would be wise to keep an open mind as they may have to radically change their preconceptions as new research emerges on some unexpected benefits of so-called 'alien' species (Hamilton, 2011).

## The development of the debate in urban Britain

In the early 1970s, the 'natives versus aliens' debate began to focus increasingly on urban areas of Britain, prompted by the growing interest in the flora of derelict and abandoned urban landscapes that had been highlighted in some popular books (Mabey, 1973). While the plants that had colonised these areas included numerous exotics such as buddleia and sycamore, many conservationists were particularly interested in the native plants that had managed to become established.

### The birth of urban ecology

In the 1970s, as the fascination with this 'flora of dereliction' increased, urban ecology developed into a recognisably separate discipline (Nicholson-Lord, 1987). The intellectual framework supplied by this new field of study then helped to prompt the emergence of an urban greening movement, partly underpinned by ideas that focused on urban wildlife and native species.

In response to what was perceived as the drab and increasingly inappropriate landscapes of many public open spaces, some landscape architects began advocating a more radical approach that contrasted sharply with management based on traditional 'horticultural' values (McHarg, 1969; Laurie, 1979). Influenced by recent developments in the Netherlands and Sweden, they began to promote 'an ecological approach to urban landscape design' that was seen as a refreshing contrast to the unimaginative and 'sterile' landscapes of the past (Ruff and Tregay, 1982). It was argued that by creating balanced plant communities of predominantly native species, and ensuring wide species interaction and diversity, high levels of nutrient recycling and wildlife habitats, the environmental quality of cities could be significantly improved. This approach was also believed to bring reduced management costs in comparison with more formal landscapes.

Many local authorities (LAs) in Britain responded to this new focus on urban ecology and nature conservation by producing strategy documents designed to deliver this. Leicester, a large city in the East Midlands, was one of the first LAs to adopt a city-wide ecology strategy (Moughtin and Shirley, 2005). While it was called an ecology strategy and ostensibly focused on nature conservation, it also described itself as adopting an innovative approach to landscape planning and management for the city's full range of open spaces (Leicester City Council, 1989). Throughout the 1980s and 1990s, many other LAs followed Leicester's example and produced similar strategies. These also tended to emphasise the value of native species of trees and shrubs and advocate the limitation of exotics.

## Opposition to the 'natives are best' agenda

While recognising the high nature conservation value of some native species, especially in rural areas, many landscape professionals had major reservations about promoting mainly native trees and trying to create extensive areas of semi-natural landscapes in urban areas. Henry Arnold (1992), an eminent American landscape architect, challenged the approach in terms of its relevance to urban design and questioned the value of plant ecology in formulating rules for planting in cities.

In Britain, a paper in the *Arboricultural Journal* reflected the views of an increasing number of LA tree officers by challenging the appropriateness of this approach to urban landscape in what were essentially human habitats (Johnston, 1983). Another critical British paper had a greater impact as it was published in *Ecos*, a journal widely read and respected by the ecology and conservation sector (Fenton, 1986). Although it did not focus specifically on urban areas, it ignited some vigorous debate on the overall topic. Perhaps aware of the growing opposition to a strict 'natives only' agenda being applied to towns and cities rather than just rural areas, arguments in favour of this approach for urban landscapes began to be couched in the more subtle 'natives are best' agenda.

Just as that debate was escalating, an event occurred that brought it into a very practical focus. In the early hours of 16 October 1987, hurricane-force winds swept across the South and East of England destroying some 15 million trees (Ogley, 1988). 'The Hurricane' (also called The Great Storm) ensured that trees and tree planting suddenly gained national attention to an unprecedented extent. While rural areas also suffered, much of the public and media attention focused on its impact in towns and cities. Some prominent conservation groups saw this as an opportunity to promote their 'natives are best' agenda. While trying to cope with a massive clear-up operation, several LA tree officers in London were irritated by phone calls from the London Wildlife Trust asking for assurances that at least 60% of street tree replacements would be native trees (Johnston, 1991). They regarded this demand for quotas, a logical development of the 'natives are best' agenda, as totally inappropriate in urban planting schemes.

Following the widespread negative reaction among urban landscape professionals to this 'natives are best' agenda, the debate subsided. However, in the past decade it has been reignited and many of the old arguments are being recited again.

## Re-emergence of the 'natives are best' agenda

The basic ideas that initially motivated the ecological approach to urban landscape design and the urban wildlife movement were understandable. However, these ideas seemed to get 'hijacked' into an agenda that had little to do with the original ideas or the different requirements of multifunctional urban landscapes. Something similar is happening again.

Concern worldwide about diminishing biodiversity has been translated into local initiatives to reverse this decline and protect and restore threatened species and habitats. Under the Natural Environment and Rural Communities (NERC) Act 2006, LAs in England and Wales have a major role to play in the conservation of biodiversity (The Wildlife Trusts, 2007). Local Biodiversity Action Plans (BAPs) are a key part of this. While concerns about global biodiversity may be well founded, this is once again in danger of being seized upon to promote a 'natives are best' agenda for urban areas in Britain. Even worse, there is a danger of taking this to the extreme of proposing quotas for native trees in urban planting schemes.

Some BAPs include general statements and policies that favour the planting of native species of trees, shrubs and other plants, often with little thought as to whether this is an urban or rural location. The Local Biodiversity Action Plan for Belfast in Northern Ireland has a particularly stark and uncompromising stand in favour of native species (Belfast City Council, 2007). In a section of the document entitled 'Why are native species important', the last paragraph states:

*While priority should be given to native species, it is recognised that under special circumstance non-natives will be important. Examples of this include features in historic landscapes or special collections such as those in Belfast Zoo or the Botanic Gardens.*

The idea that in a major urban area such as Belfast non-native trees and shrubs should be confined to 'special areas' is not only inappropriate and even slightly sinister, it also fails to take account of the reality of the situation. Like almost every city in the developed world, Belfast already has huge numbers of non-native trees in street, parks, open spaces and private gardens (Segoviano, 1995).

This general preference for native species in many BAPs may be having an influence on LA tree strategies, even those that cover predominantly or exclusively urban areas. In the Tree Strategy for Arun District Council (2005), the section on biodiversity contains the sweeping statement that 'native species of tree create more [biodiversity] benefit than non-native species.' Then, in the section on meeting the objectives of the strategy, it states: 'use of native species is preferred wherever planting takes place. Non-natives species will be restricted to formal parks.'

A recent attempt to promote native trees and other plants for residential gardens gained national prominence. In 2008, the *Daily Mail* reported that Monty Don, the presenter of BBC TV's 'Gardeners World', had declared that British gardeners should only use native plants in their gardens (Camber, 2008). This reversion to the strict 'natives only' agenda prompted widespread opposition, particularly from gardeners and professional horticulturists (Appleby, 2008).

The British government's recently launched 'The Big Tree Plant', an initiative to plant one million new trees in towns and cities in England, also seems to have been influenced by the 'natives are best' agenda. While this initiative is specifically about tree planting in urban areas, there are various links on its website to advisory material on tree planting which clearly state a preference for planting native trees.

# How appropriate are native species for urban Britain?

When the 'natives versus aliens' debate emerged among landscape professionals in the 1970s, our knowledge of the many benefits of urban trees was at an early stage. Furthermore, much of that initial research had been conducted in North America and was not widely known among relevant British professionals (Robinette, 1972). This may have encouraged a rather limited perspective of those benefits with a heavy emphasis on the role of urban trees in ecology and nature conservation. With more extensive research in recent years, there is now a far more detailed understanding of the many environmental, economic and social benefits of urban trees (NUFU, 2005; Hiemstra *et al*., 2008; Forest Research, 2010). Furthermore, thanks largely to the internet, much of that research is freely available.

The ways in which that research is applied are also changing. The urban forest manager now has to ensure that the trees and woodlands in our towns and cities deliver a wide range of benefits for the people who live and work there. In difficult financial times, there are also major considerations about the cost of delivering those benefits and whether management priorities reflect value for money. In the light of research, current management imperatives and the re-emergence of the 'natives versus aliens' debate, the authors believe it is time to assess that debate's relevance to modern urban forest management, asking in particular whether a general preference for so-called native trees in urban areas can be justified in Britain.

In recent years, the 'natives are best' agenda when applied to urban areas in Britain has been challenged by a wide range of academics and an increasing amount of relevant research. It is worth highlighting some of this by examining a range of factors that can influence the selection of urban trees and explore how native species meet these requirements.

## Biodiversity and conservation

Biodiversity literally means the variety of life on Earth. It is normally applied to the variety of life in any given ecosystem and is often regarded as a measure of the health of that ecosystem. To simply equate biodiversity with native species is to misunderstand the true meaning of biodiversity. Then, to use biodiversity as an argument for promoting the 'native are best' agenda for trees in urban areas is a clear distortion of the term.

An examination of the current urban tree population in Britain reveals this is extremely diverse due to the presence of non-native trees. An astonishing 1360 different taxa have been recorded in public urban sites (Johnson, 2005). Data from the government's *Trees in Towns II* report show that non-native trees have a very high profile in our urban landscapes (Britt and Johnston, 2008). If the aim is to promote biodiversity in urban areas, why just select those few native tree species that are likely to thrive in the intensely demanding urban environment? This will restrict biodiversity and limit the delivery of a wide range of tree benefits in different site conditions.

One of the 'golden rules' of tree selection for urban areas is to maintain a diversity of tree species for sound management reasons. Since tree pests and diseases tend to be selective, a landscape with a variety of species will typically suffer fewer losses when an outbreak does occur. Frank Santamour's (1990) '10–20–30' formula to develop a diverse tree population within the urban forest is straightforward: no more than 10% of any species, 20% of any genus or 30% of any family. If choice was limited to only native species, this would be almost impossible to apply and also ensure a healthy and vibrant urban forest.

In order to meet the requirement to favour 'native' trees that appears in many BAPs, some landscape architects and tree officers have chosen cultivars of native species such as *Quercus robur* 'Fastigiata', *Tilia cordata* 'Greenspire' and *Sorbus aucuparia* 'Joseph Rock' (Sacre, 2011, pers. comm.) in streets and other restricted urban spaces. These trees have a crown form or size more suited to some narrow streets than the original species (Figure 1). However, they are specifically bred and genetically identical cultivars that cannot be described as native trees in the conventional use of that term. Indeed, many of them have been purchased as containerised trees from overseas suppliers. This seems a strange way to meet biodiversity objectives.

**Figure 1** A fastigiate oak used as a street tree.

One of the most common arguments in favour of selecting native trees for urban areas is their conservation value in encouraging associated wildlife. Conservationists are often keen to quote data in support of this. The statement that an oak tree can support over 400 species of invertebrates frequently appears in conservation literature (Alexander *et al*., 2006) and in some BAPs (Rushmore Borough Council, 2009) and LA tree strategies, even for urban areas (Manchester City Council, 2006). However, conservationists themselves recognise that no one tree on one site supports this number and a wide range of factors can influence any tree's ability to realise its conservation potential (Alexander *et al*., 2006). While the conservation value of many of our native trees may be significant in urban woodland, most of our urban forest is comprised of individual and small groups of trees in close proximity to buildings, streets, traffic, utility services, etc. An oak in a busy city centre street with paved surfaces, high levels of pollution and poor soil conditions will support a very limited number of species of invertebrates.

It should be remembered that native tree species also vary considerably in their potential to support wildlife and in comparison to oak (*Quercus robur* and *Quercus petraea*) some have a relatively poor ability (Alexander *et al*., 2006). At the same time, many non-native trees can have a surprising high potential. To reduce all this to a simple 'natives are good, aliens are bad' approach is to ignore the complexity of the research evidence.

## Size of the planted area and wildlife gardening

Even at an early stage in the promotion of an ecological approach to urban landscapes design, it was appreciated that the size of an area was a significant consideration in achieving the desired outcome (Cole, 1982). Since the creation of semi-natural habitats requires the removal of urban constraints, the problems of space arises (Johnston, 1983). Plant diversity and innate stability tend to increase with the size of the habitat. Conversely, the smaller the habitat created, the greater the management input required to maintain diversity and stability and to control the effects of public use. It has been suggested that a small woodland ecosystem of less than 1.0 ha with associated ground flora should only be attempted where there is a definite commitment to frequent and sensitive management and public access is restricted owing to isolation or positive control (Cole, 1982). How can this be reconciled with low maintenance costs and providing public amenity? Indeed, making space in our built environment for even one large-growing tree is proving increasing difficult, let alone woodland, and has promoted a trend towards small ornamental trees which offer quite limited benefits (TDAG, 2010).

While it may be accepted that trying to establish significant areas of semi-natural woodland using native species is problematic in urban areas, many conservationists would argue that native species are best when planning the revegetation of extensive areas of brownfield land. However, according to studies undertaken by Forest Research, this is often not the case (Moffat, 2006). Even if woodland creation and increased biodiversity are major long-term aims, there are excellent reasons for using non-native species in many situations.

Over the past few decades, conservationists have tried to encourage the public to participate in 'wildlife gardening' (Baines, 1985; Lavelle and Lavelle, 2007). This promotes the planting of native tree species in residential gardens, stressing their value to nature conservation and biodiversity. If successful, this could have a major impact on the composition of the urban forest because residential zones can account for more than 60% of urban land area in the UK (BUGS, 2007) and trees in private gardens usually account for the vast majority of trees in residential areas (Britt and Johnston, 2008).

The Biodiversity of Urban Gardens in Sheffield (BUGS) project has undertaken some extensive research to understand the role of domestic gardens in enhancing biodiversity, to explore what factors affect biodiversity in urban gardens and how effective 'wildlife gardening' is. The BUGS 1 project focused on the city of Sheffield (Thompson *et al.,* 2003; Garston, *et al*., 2005), while BUGS 2 is looking at the same issues in five cities across the UK (Loram *et al*., 2008). Far from justifying any 'natives are best' approach, the research often highlights the role of non-native plants in promoting biodiversity and supporting wildlife.

Another recent study entitled *London's Small Parks and Squares – A Place for Nature?* (Sibley *et al*., 2005) surveyed more than 290 green spaces in central London, investigating what made good sites for birds as an indicator of biodiversity. The most important element was to provide birds with the kind of habitats they required: shrubberies and 'woodland edge' cover for smaller birds, open ground for pigeons, and ivy clad trees. The overall results of the survey did not generally bring out a strong link between bird diversity and the presence of native trees and shrubs, with the exception of the house sparrow. For traditional gardens, vegetation structure is more important than species composition in determining bird diversity. The presence of trees or shrubs with edible fruits, regardless of whether they are native species, is likely to be significant for fruit-eating species.

## Urban design, air quality and climate change

Many proponents of the 'natives are best' agenda in urban planting also stress the importance of a 'natural' arrangement of these plants – so-called 'ecological' or 'naturalistic' landscapes. However, many landscape architects and other relevant professionals do not subscribe to this approach and regard it as severely limiting in terms of delivering a liveable urban landscape. A high-profile example of this 'ecological' approach was the William Curtis Ecological Park, which was created in 1976 and survived until 1985 (Figure 2). While this was a delightful naturalistic landscape in the heart of London, much used by schoolchildren studying nature conservation, some of its supporters wanted to promote this approach as a general prescription for urban landscapes (Nicholson-Lord, 1987). In *Trees in Urban Design* by Henry Arnold (1992), widely regarded to be one of the world's great books on urban design, Arnold argues against this approach and shows how trees can be used extensively as a fundamental urban design element, collectively and imaginatively. He believes that 'naturalistic' landscapes run counter to good landscape design and that the great urban spaces of the world owe their existence to artists who have consciously transformed nature. He emphasises the need for order rather than chaos in urban design and basic physical design principles.

It has long been established that urban trees and woodland can have a beneficial impact on air quality in our towns and cities and consequently on human health (Bernatzky, 1978). Trees can remove pollutants, especially ozone, nitrogen oxide and particulate matter from the air. Not all trees are equally effective and the impact of different trees on the reduction of different pollutants is a complex subject. What is not widely known is that some trees have a negative impact on air quality, mainly through the emission of volatile organic compounds (VOCs). Researchers at Lancaster University's Centre for Ecology and Hydrology have attempted to produce a scoring system that focuses on the ability of different trees to improve air quality (Stewart *et al*., undated). Known as the Urban Tree Air Quality Score (UTAQS), it measures the ability of trees on a scale ranging from 'Best' (trees with the greatest capacity to improve air quality) through to 'Worst' (trees with the potential to worsen air quality). Trees listed in the 'Worst' category in a brochure to publicise this work are crack willow, English oak, goat willow, poplar, red oak, sessile oak and white willow. It should be noted that all but one of these is a native tree.

Arguably the greatest challenge that humans face in this century is that of climate change, which will impact across the globe. Temperatures in our towns and cities are going to

**Figure 2** The William Curtis Ecological Park in the heart of London, photographed in 1982.

continue to rise, although the rate and extent of this will depend on many factors. Trees that previously thrived in urban areas may start to decline and better adapted species of trees will have to be planted. Recent research has shown that trees can play a vital role in urban climate adaptation, with the larger-growing tree species providing significantly greater benefits for urban cooling (Ennos, 2010). The choice of species to meet this requirement, and still survive in demanding urban locations, will over-ride any considerations about native or non-native species.

Climate change will also have a significant impact on water availability across the country (Knox *et al.*, 2008). Lack of water and increased periods of drought will put further strain on existing trees and new plantings will need to favour more drought-resistant species. The ability of trees to cool urban temperatures is also dependent on adequate access to water for evapotranspiration. Some urban areas will see an increase in flooding incidents as extreme weather patterns develop. The role of trees in Sustainable Urban Drainage Systems (SUDS) to regulate water run-off, promote rainfall infiltration and control pollution and sediment retention are now widely recognised (Forest Research, 2010). However, while research highlights species selection as a very significant criterion in SUDS, there is little consideration about whether species are native or non-native (Gammie, 2011, pers. comm.). The broader the range of species to choose from, the better the chance of selecting trees that will survive and function adequately in these usually very demanding environments.

## Signposts for the future

In the light of the research outlined above and other relevant studies, it is clear that an automatic preference for native trees when planting in urban areas cannot be justified. We need a far more balanced and sustainable approach to urban tree selection, based firmly on science rather than emotion or prejudice. In essence, what we need to do in any given location is to match the benefits we require from urban trees with the species that are best able to deliver this. Of course, in practice the matter is rather more complex. While a species may be excellent at delivering certain benefits, it may also have some other qualities that make it unsuitable for a particular site. Tree selection is almost always a balance between trying to achieving the desired effect together with having the least possible negative impact.

In a changing world, growing conditions for urban trees seem to become increasingly demanding. Climate, soil conditions, pests and diseases, and lack of space above and below ground are just some of the factors that are in danger of drastically reducing the number of trees in our towns and cities. In order to plan for extensive and vibrant urban forests in the future, we need to take account of these changes, and respond to them with appropriate tree selection. This needs to be a long-term view for perhaps the next 100 years, the possible lifespan for some large-growing urban trees.

## Environmental assessments and ecosystem services

Landscape and other relevant professionals need to be better informed about the benefits of urban trees and how best these can be achieved. In recent years, we have seen the development of some assessment criteria that attempt to give guidance on tree and plant selection in different locations and situations.

In the UK, BREEAM (BRE Environmental Assessment Method) is the leading and most widely used environmental assessment method for buildings. It claims to set the standard for best practice in sustainable design and has become the *de facto* measure used to describe a building's environmental performance (BRE, 2009). The BREEAM Communities Scheme aims to help planners and developers improve, measure and independently certify the sustainability of development proposals at the planning stage (BRE, 2011).

BREEAM assessments emphasise and encourage the use of native plants, referring in BREEAM Communities to quotas of native trees (BRE, 2011). This is a concern because it does not appear to take account of urban conditions in Britain and of the need for a far more flexible approach to deliver environmental, social and economic benefits for those who live and work in our towns and cities. The authors believe that the BREEAM approach is too simplistic and it needs to be revised to take account of relevant research on the selection, planting and management of urban trees.

'Ecosystem services' is a term that is increasingly used to describe a multitude of processes and resources supplied by natural ecosystems to the benefit of humans and the overall environment. However, care should be taken when applying this to the urban and built environment where these ecosystems have been highly disrupted and/or regulated by human activity. The authors propose that, in terms of tree species selection, the approach to decisions regarding tree species should be as balanced as possible taking into account all relevant factors while still following best practice of an ecosystems services approach. This may entail the selection of non-native species as being more suitable for streets and hard-surfaced areas, while parks, green spaces and gardens could accommodate a greater variety of both native and non-native species.

As we learn more about the many benefits which trees can deliver in the urban realm and also how trees behave in various locations, the factors to take into account when selecting appropriate species are getting more complex. However, we need to consider these factors if we are to make the right choices for long-term tree growth and achieve the significant increases in our urban forest cover which climate change and other challenges require. Furthermore, all this needs to be reflected in the content of BAPs and other relevant strategies.

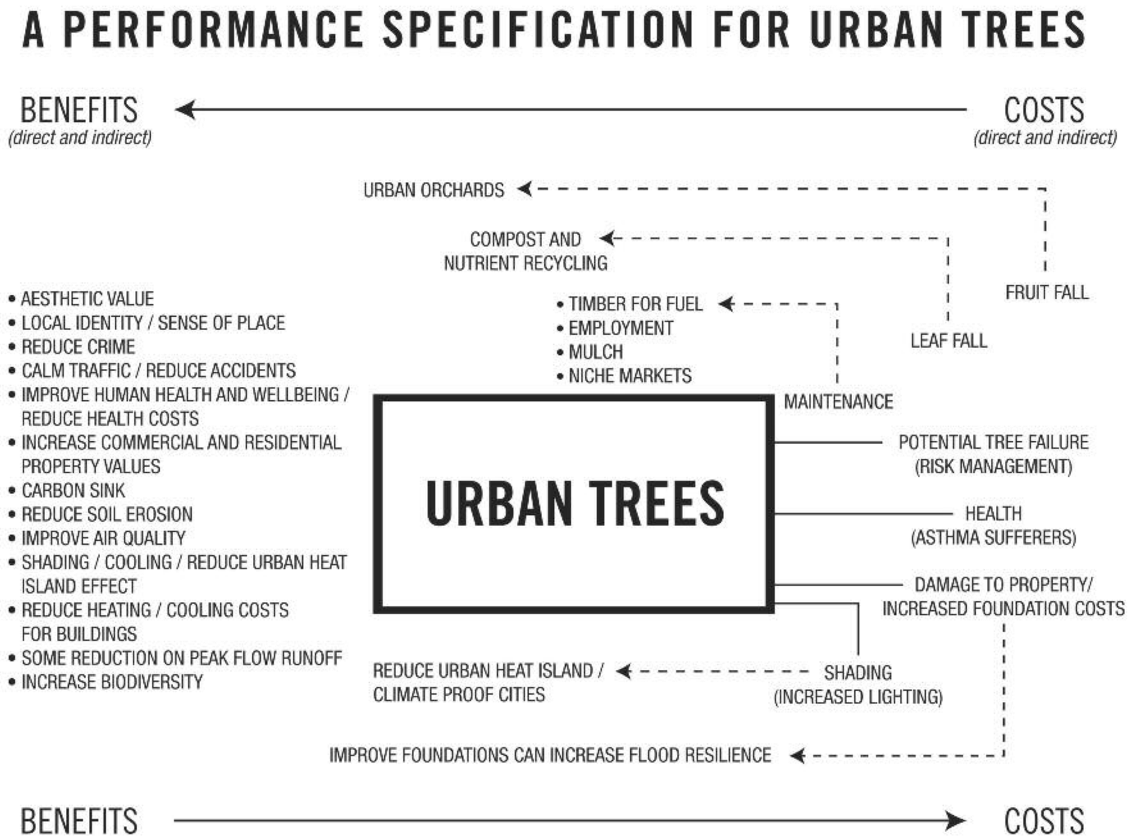
## Urban tree score

The report from the Centre for Ecology and Hydrology ((Stewart *et al*., undated) proposed the creation of an 'urban tree score' where the benefits of trees as well as their disadvantages (such as damaging property and high maintenance requirement) were incorporated onto a scale. This approach seems a good model for adding in all the social, environmental and economic benefits of various tree species and the costs they can incur such as tree maintenance, leaf fall, possible increased construction expenditure and potential property damage. We can then give a score for trees in different locations such as streets, parks, industrial estates and residential gardens. In this way we might really find the right place for the right tree and take a positive step towards ensuring we are making choices which will deliver the greatest number of long-term benefits to outweigh any possible disadvantages. Figure 3 is an attempt to present diagrammatically the essence of this approach for a performance specification for urban trees.

# Conclusion

The city is not a natural habitat but a human habitat which displays a unique heritage of landscapes involving a mix of native and non-native tree species. The 'natives only' or 'natives are best' approaches which have recently resurfaced are evidence of a biocentric view that has limited relevance to the modern city. The advocates of these approaches appear intent on reversing some 2000 years of gardening tradition in Britain by reverting to some kind of idyllic past of semi-natural landscapes that existed before humans engaged in built development. This will inevitably lead to

**Figure 3** A performance specification for urban trees.




urban landscapes with quite limited environmental, economic and social benefits. Furthermore, this would occur at a time when we need greater not less flexibility in responding to the ever-increasing challenges of establishing and maintaining healthy and vibrant urban forests in the built environment.

The aim of urban forestry is to improve the welfare of urban residents; the planting and care of trees is a means to that end, not an end in itself (Johnston, 1985). The 'natives only' and 'natives are best' agendas are a reversal of this position which attempts to put the promotion of a particular group of plants in our towns and cities before the welfare of their urban residents. This may be another example of what Alston Chase (1995) describes as the 'rising tyranny of ecology'.

Recent research has shown that we need much more specific research on the selection of urban trees in the future to meet a wide range of environmental, economic and social objectives. Only then can we make intelligent, holistic assessments on species choice and whether these should be native or non-native contributions to the urban forest.

## References


ALEXANDER, K., BUTLER, J. AND GREEN, T. (2006). The value of different tree and shrub species to wildlife. *British Wildlife*, October 2006, pp. 18–28.

APPLEBY, M. (2008). Stick to native plants, say Don. *Horticulture Week*, 17 April, p. 9.

ARNOLD, H. (1992). *Trees in Urban Design*. Second edition. Van Nostrand Reinhold. 192 pp.

ARUN DISTRICT COUNCIL (2005). *Tree Strategy 2005*. Parks and Greenspaces Department, Arun District Council.

BAINES, C. (1985). *How to Make a Wildlife Garden*. Elm Tree Books. 192 pp.

BELFAST CITY COUNCIL (2007). *Local Biodiversity Action Plan for Belfast*. Parks and Cemeteries Section, Belfast City Council. 40 pp.

BERNATZKY, A. (1978). *Tree Ecology and Preservation.* Elsevier Scientific Publishing Company. 357 pp.

BRE (2009). *BREEAM: The environmental assessment method for building around the world*. Building Research Establishment. 6 pp.

BRE (2011). *BREEAM for Communities: Stage 2*. SD5065 Technical Guidance Manual: Version 1. Building Research Establishment. 498 pp.

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II: A new survey of urban trees in England and their condition and management*. Department for Communities and Local Government. 644 pp.

BROWN, N. (1997). Re-defining native woodland. *Forestry* **70**(3), 191–198.

BROWNE, D. (1996). *Our Trees: A guide to growing Northern Ireland's native trees from seed*. Conservation Volunteers Northern Ireland. 72 pp.

BUGS (2007). *Biodiversity of Urban Gardens in Sheffield (BUGS) project*. *Background: Urban gardens as habitats.* [Online] Available at: http://www.bugs.group.shef .ac.uk/BUGS1/backgrnd.html [Accessed 06/03/11].

CAMBER, R. (2008). Yew must be joking! *The Daily Mail*, Saturday 26 April, p. 31.

CHASE, A. (1995). *In a Dark Wood: The fight over forests and the rising tyranny of ecology*. Houghton Mifflin. 535 pp.

COLE, L. (1982). Does size matter? *In:* Ruff, A.R. and Tregay, R. (eds.) *An Ecological Approach to Urban Landscape Design*. Occasional Paper Number 8. Department of Town and Country Planning, University of Manchester. 144 pp.

DENNE, M.P. (1987). Is sycamore native to Britain? (Correspondence). *Quarterly Journal of Forestry* **81**(2), 201.

DERBYSHIRE, D. (2011). The new knotweeds. *The Daily Mail*, 1 March, p. 34.

ENNOS, A.R. (2010). Urban cool. *Physics World* **23**(8), 22–25.

FENTON, J. (1986). Alien or native? *ECOS* **7**(2), 20–23.

FOREST RESEARCH (2010). *Benefits of green infrastructure*. Report to DEFRA and CLG. Forest Research, Farnham. 196 pp.

GAMMIE, M. (2011). Personal communication in the form of an email from Martin Gammie, CABE research scholar, to Mark Johnston on 1 March 2011.

GASTON, K.J., SMITH, R.M., THOMPSON, K. AND WARREN, P.H. (2005). Urban domestic gardens II: experimental tests of methods for increasing biodiversity. *Biodiversity and Conservation* **14**, 395–413.

GIL, L., FUENTES-UTRILLA, P., SOTO, A., CERVERA, M.T. AND COLLADA, C. (2004). English Elm is a 2000-year-old Roman clone. *Nature* **431**, 1053.

GILPIN, W. (1794). *Remarks on Forest Scenery and other Woodland Views*. Second edition. R. Blamire in The Strand, London. Vol. 1: 340 pp., Vol. 2: 310 pp.

HAMILTON, G. (2011). Aliens to the rescue. *New Scientist*, **209**(2795), 34–37.

HARRIS, E. (1987). The case for sycamore. *Quarterly Journal of Forestry* **81**(1), 32–36.

HIEMSTRA, J., SCHOENMAKER, E. AND TONNEIJCK, A. (2008). *Trees: Relief for the City*. Plant Publicity Holland. 33 pp.

JOHNSON, O. (2005). A study of biodiversity in UK urban tree populations. *Arboricultural Journal* **29**, 55–62.

JOHNSTON, M. (1983). Urban trees and an ecological approach to urban landscape design. *Arboricultural Journal* **7**, 275–282.

JOHNSTON, M. (1985). Community Forestry: a sociological approach to urban forestry. *Arboricultural Journal* **9**, 121–126.

JOHNSTON, M. (1991). The Forest of London: 1 – Planting an idea. *Arboricultural Journal* **15**, 127–143.

JOHNSTON, M. AND SHIMADA, L. (2004). Urban forestry in a multicultural society. *Journal of Arboriculture* **30**(3), 185–192.

KENDLE, A.D. AND ROSE, J.E. (2000). The aliens have landed! What are the justifications for 'natives only' policies in landscape planting? *Landscape and Urban Planning* **47**, 19–31.

KNOX, J., WEATHERHEAD, K. AND KAY, M. (2008). *Climate change impacts on water for horticulture*. Environment Agency and Cranfield University. 12 pp.

KRAJIK, K. (2005). Winning the war against island invaders, *Science* **310**, 1410–1413.

LAURIE, I.C. (ED.) (1979). *Nature in Cities: The Natural Environment in the Design and Development of Urban Green Space*. John Wiley and Sons. 428 pp.

LAVELLE, C. AND LAVELLE, M. (2007). *The Illustrated Practical Guide to Wildlife Gardening*. Anness Publishing Ltd. 256 pp.

LEICESTER CITY COUNCIL (1989). *Leicester City Council Ecology Strategy*. Ecology Advisory Group, Leicester City Council. 99 pp. with appendices.

LORAM, A., WARREN, P.H. AND GASTON, K.J. (2008). Urban domestic gardens (XIV): the characteristics of gardens in five cities. *Environmental Management* **42**, 361–376.

MABEY, R. (1973). *The Unofficial Countryside*. William Collins and Sons. 173 pp.

MCHARG, I.L. (1969). *Design with Nature*. The American Museum of Natural History, The Natural History Press. 198 pp.

MANCHESTER CITY COUNCIL (2006). *Manchester Tree Strategy 2006 – 2010*. Environmental Services, Manchester City Council.

MARRIS, E. (2005). Shoot to kill. *Nature* **438**(7066), 272–273.

MITCHELL, A. (1981). *The Native and Exotic Trees in Britain*. Arboriculture Research Note 21–81–SILS. Published for the Department of the Environment, Arboricultural Information Service, by the Forestry Commission.

MOFFAT, A. (2006). *Native and Non-Native Trees: Why and How Do We Choose?* BPG Note 8, Best Practice Guidance for Land Regeneration. Forest Research, Forestry Commission.

MOUGHTIN, C. AND SHIRLEY, P. (2005). *Urban Design: Green Dimensions*. Second edition. Elsevier.

NICHOLSON-LORD, D. (1987). *The Greening of the Cities*. Routledge and Kegan Paul. 270 pp.

NUFU (2005). *Trees Matter! Bringing lasting benefits to people in towns*. National Urban Forestry Unit. 20 pp.
OGLEY, B. (1988). *In the Wake of the Hurricane*. National Edition. Froglets Publications. 140 pp.
RICHARDSON, D., PYSEK, P., REJMANEK, M., BARBOUR, M., PANETTA, F. AND WEST, C. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* **6**, 97–107.
ROBINETTE, G. (1972). *People, Plants, and Environmental Quality*. United States Department of the Interior, in collaboration with the American Society of Landscape Architects Foundation. 140 pp.
RUFF, A. AND TREGAY, R. (EDS.) (1982). *An Ecological Approach to Urban Landscape Design*. Occasional Paper Number 8. Department of Town and Country Planning, University of Manchester. 144 pp.
RUSHMORE BOROUGH COUNCIL (2009). *Rushmore Biodiversity Action Plan 2009–2014*. Environmental Services, Rushmore Borough Council.
SACRE, K. (2011). Personal communication in the form of an email from Keith Sacre, Sales Director of Barcham Trees plc, to Mark Johnston on 2 March 2011.
SANTAMOUR, F.S. (1990). *Trees for Urban Planting: Diversity, Uniformity, and Common Sense*. Proc. 7th Conf. Metropolitan Tree Improvement Alliance. METRIA **7**, 57–65.
SEGOVIANO, A. (1995). *Belfast's Trees: A Survey of Trees in the Greater Belfast Area*. The Forest of Belfast Project. 33 pp.
SIBLEY, P., HEWLETT, J., VICKERS, D., GANNAWAY, C., MORGAN, K. AND REEVE, N., (2005).*London's small parks and squares – a place of nature?* The London Parks and Greenspaces Forum.
SOMMER, R. (2003). Trees and human identity. *In:* Clayton, S. and Opotow, S. *Identity and the Natural Environment: The psychological significance of nature.* Massachusetts Institute of Technology, pp. 179–204.
STEWART, H., OWEN, S., DONOVAN, R., MACKENZIE, R. AND HEWITT, N. (UNDATED). *Trees & Sustainable Urban Air Quality*. Centre for Ecology and Hydrology, University of Lancaster. 12 pp.
TDAG (2010). *No Trees, No Future: Trees in the Urban Realm*. Trees and Design Action Group. Revised edition edited by CABE and English Heritage. 27 pp.
THE WILDLIFE TRUSTS (2007). *Local Authority Services and Biodiversity: Your Statutory Obligations.* The Wildlife Trusts. 8 pp.
THOMAS, S. (2010). *Here Today, Gone Tomorrow: Horizon scanning for invasive non-native plants*. Plantlife. 20 pp.
THOMPSON, K., AUSTIN, K.C., SMITH, R.M., WARREN, P.H., ANGOLD, P.G. AND GASTON, K.J. (2003). Urban domestic gardens (I): putting small-scale plant diversity in context. *Journal of Vegetation Science* **14**, 71–78.
WEBB, D.A. (1985). What are the criteria for presuming native status? *Watsonia* **15**, 231–236.

# Strategies for exploring urban futures in, and across, disciplines

## Abstract

The EPSRC Urban Futures project aims to assess the resilience of urban regeneration to a range of possible futures. The project uses narrative scenarios, rather than quantitative extrapolation techniques. Some scenario storylines include tipping points and paradigm shifts, leading to societal patterns quite different from those in the present day UK. The scenarios are honed from existing futures literature by deducing characteristics of each scenario that are relevant for urban regeneration. To make these deductions, each scenario is interrogated from eight disciplinary standpoints: biogeography, air pollution, water resources, the surface built environment, the underground built environment, design, organisational behaviour, and social policy. The refined scenarios are then used as 'test rigs' in which the resilience of current regeneration strategy and practice can be assessed.

Trees and green space in cities have emerged as a cross-cutting theme in Urban Futures. Street trees, parkland, and green walls and roofs are often cited as important contributors to the sustainability of a regeneration project. We discuss our strategy for assessing such claims, using the West Midlands and Lancaster as UK case study areas, and provide examples of project outcomes (building on our previously published Urban Tree Air Quality Score). We also describe the limits to our assessments, which are due to (i) the scope of the scenarios used, (ii) difficulties in passing useable information between disciplines and/or (iii) discipline-specific technical limitations (e.g. incorporating the aerodynamic, thermal, and chemical effects of trees and green spaces in models of urban air pollution).

## Introduction

Across the world, most people now live in cities (http://nature.com/cities and references therein). These cities are diverse, but they all contribute to, and must adapt to, the changing environment. Hence, most environmental, economic, and social planning and policy-making for cities advocates sustainable development. Many remedial actions have been proposed in response to the widely acknowledged unsustainability of contemporary urban living (Droege, 2006; Roger Evans Associates *et al*., 2007; Beatley, 2010; Gehl, 2010; Suzuki *et al*., 2010). Below, we refer to specific remedial actions as 'sustainability solutions' or, simply, 'solutions'. Very many sustainability solutions involve significant increases in urban green space: installation of green walls, green roofs, and other 'living infrastructure' (Hollander *et al*., 2010), expansion of parkland (Harnik and Bloomberg, 2010; Suzuki *et al*., 2010, p.76), and planting many more street trees (http://thebigtreeplant.direct.gov.uk/about.html). In what follows we concentrate on sustainability solutions that have been proposed in the context of urban regeneration, and on solutions that involve urban vegetation.

Our research, described below, concerns the claims to sustainability of solutions in two respects: (i) the discipline-specific evidence base for particular solutions, and (ii) the multi-disciplinary evidence base for the resilience of solutions, as measured against a range of future scenarios. This research is part of the Urban Futures project (http://urban-futures.org/), which has the multi-disciplinary assessment of sustainability solutions at its core and is informed by disciplinary-based research in biogeography, air pollution, water resources, the surface built environment, the underground built environment, design, organisational behaviour, and social policy.

Below, we describe a method to establish the resilience of sustainability solutions for urban regeneration that draws on futures research and a multi-disciplinary perspective. We begin

**Keywords:**

trees and urban design, futures scenarios, urban regeneration

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with a brief description of how scenarios can be used to establish a range of settings in which the solution must be capable of functioning. We then derive from our chosen future scenarios characteristics that are specific to UK urban environments, and provide examples of applying this scenario-based method to a specific planning case in Lancaster, UK. From this we generalise some aspects of work on trees and green spaces as sustainability solutions, using the West Midlands, UK, as an example. Finally, we acknowledge the limitations that remain in our methodology as a result of the difficulties of multi-disciplinary work and the requirement for further disciplinary research.

## Futures scenarios

Our approach to the use of future scenarios is described in detail elsewhere (Hunt *et al*., 2011). Briefly, our approach requires the use of future scenarios, rather than extrapolation, because resilience implies continued functioning across a range of possible futures, ranging from the probable to the plausible. Scenario-building allows for social, economic, or environmental tipping points in a way that extrapolation cannot (Slaughter, 1995; Fischer-Kowalski and Halberl, 2007; Samet, 2008). Another key distinction between futures research and extrapolation is picked up in our conclusions. A survey of recent futures literature found more than 400 future scenarios (Hunt *et al*., 2011). Rather than add to this list, we elected to use existing scenarios and develop their treatment of (UK) urban characteristics, as described below.

Our chosen scenarios come from the work of the Global Scenarios Group (GSG): see http://www.gsg.org/, for general introductory material on GSG, and http://www.polestarproject.org/globalscen.html for more quantitative technical details. We develop the GSG descriptions of Market Forces, Policy Reform, New Sustainability Paradigm, and Fortress World scenarios. These scenarios cover extrapolated conventional or business-as-usual futures (Market Forces, which was originally called 'Business-as-usual', and Policy Reform), a future characterised by civil breakdown or barbarisation (Fortress World), and a future in which communitarian value systems emerge (New Sustainability Paradigm).

In Market Forces (MF), as the name suggests, there is continued strong belief that the invisible hand of the market will produce, purely through the self-interest of individuals, the most good for the most people. Concerns about depletion of natural resources or contamination of the Commons are subordinated to this belief in the market as engine of economic improvement. As an extrapolated business-as-usual scenario, MF therefore includes the continued urbanisation of world population, as described in http://nature.com/cities and references therein.

The Policy Reform (PR) scenario retains the primacy of individual self-interest, but tempers the free-running of the market, through implementation of strong regulations, in order to slow the depletion of natural resources and limit the contamination of the Commons.

Since natural resources are finite, the GSG authors argue that the extrapolated MF and PR futures will inevitably collapse, to produce radically different futures. In the Fortress World (FW) scenario, the selfishness inherent in MF and PR becomes exacerbated as resources diminish, leading to enclaves of 'haves' who protect their privileged access to resources against a large majority of 'have-nots'. Because of the concentration of economic and political power in cities, the FW enclaves centre on highly developed urban areas but also encapsulate the dispersed infrastructure and utility networks that allow the enclaves to function.

The GSG authors provide an alternative to FW, in which the collapse of MF and PR causes a wholesale re-evaluation of the primacy of self-interest. The New Sustainability Paradigm (NSP) is characterised by concern for the preservation of natural systems, to the extent that individuals seek material sufficiency (rather than excess) and prefer to live in societies with equitable distributions of wealth. In order to avoid a turn towards localism, global networks are maintained, principally through the maintenance of cities and their metabolic infrastructure.

## UK urban characteristics

The GSG scenarios provide qualitative and quantitative descriptions of each future at global and continental scales. To bring futures thinking into planning practice, however, local environmental, societal, and economic contexts must be considered, in order to avoid a one-size-fits-all mind-set that imposes a single grand vision with its attendant unforeseen consequences. Local here encompasses all scales from the street corner to the city (Roger Evans Associates *et al*., 2007; Suzuki *et al*., 2010), and often extends further than expected. For instance, installation of bat boxes can only work as a solution to preserve biodiversity if unlit tree corridors, connecting the bat roosts to feeding areas, are also in place. This also implies that the topology of tree cover can be as important as overall area and species composition. Sustainability solutions can be vulnerable if they are applied without due regard to their local context even before considering the resilience of a solution to possible futures. Moreover, urban planners have in the past sometimes neglected the 'human scale' and championed designs in which the aesthetic value becomes apparent only when seen from a distance or even from the air (Gehl, 2010), and it is important that futures thinking about city living does not make the same mistake.

To down-scale the scenarios to the scales relevant for urban planning and regeneration, we have identified over 50 characteristics that describe the aspects of the UK urban environment relevant to the Urban Futures research (the full list of characteristics is available at http://urban-futures.org/). These characteristics range from population density, through brownfield recycling, above-ground and underground infrastructure, street patterns, and traffic levels, to levels of personal income and patterns of ownership. We have then used the evidence presented in the descriptions of the scenarios to deduce how each urban characteristic will change under each scenario (Boyko *et al*., 2011).

An example may serve to illustrate the method. Two important characteristics of the UK urban environment are (i) area and pattern of tree cover, and (ii) tree species present. We can know the present situation with regard to tree cover through remote sensing (Huang *et al*., 2007) and with regard to tree species abundance through survey work (Donovan *et al*., 2010, whose survey results are available at http://urgent.nerc.ac.uk/dataset%20html%20pages/dataset_2066225676.htm). The descriptions of the scenarios provide evidence for the direction of travel of these characteristics: in the MF scenario, social and environmental concerns are secondary (Raskin *et al*., 2002). Maintenance of protected forest areas and biodiversity is hampered by the free market (Gallopin *et al*., 1997; Raskin *et al*., 1998). This may also apply to city parks. There is a need for high-density housing for people with low income. Income disparity between rich and poor is manifested in environmental inequality, where the rich have disproportionate access to nature reserves. From these descriptions we deduce that the change in tree cover in this scenario depends on the affluence of the area under study. Under MF, tree/hedge coverage may be static or even increase in affluent areas, but may be virtually eliminated in poor neighbourhoods due to space considerations and the cost of maintenance. Tree planting in affluent areas will be dictated by fashion, with a tendency towards planting non-native exotics. The NSP description also provides many signposts for the likely change in tree cover and speciation under that scenario. In a NSP future, large native trees are protected for their intrinsic biodiversity value. New planting is with native species where possible and located to facilitate connectivity. More fruit trees are planted because citizens value local and self-reliant production and amenity land is converted to be agriculturally productive (Gallopin *et al*., 1997). Hedges and boundary trees are planted for microclimate modification and/or fruit/wood production and/or biodiversity, rather than privacy (hence brambles rather than leylandii) because a new sense of community springs up (Gallopin *et al*., 1997). In general, people place a high value on nature (deduced from the NSP storyline in Gallopin *et al*., 1997) and there is a renaissance in craft production. More biomass species (poplar and willow) are planted to give decentralised renewable energy (Gallopin *et al*., 1997). For all these reasons, tree cover is likely to increase under the NSP scenario, subject to the particular constraints of a given locale.

## Trees and green space as sustainability solutions

It is often regarded as self-evident that there should be more trees in towns. When discussing aspects of building 'the Renewable City', Droege (2006) writes 'at the very least, streets should always be heavily lined with trees'. Whilst happy to acknowledge the many beneficial effects of urban trees, we have argued elsewhere (MacKenzie *et al*., 2010) that ensuring that trees provide a continuing positive outcome – that is, act as sustainability solutions in the strict sense – requires careful consideration of competing and shifting costs and benefits. From an air quality perspective, all urban trees provide efficient surfaces for the dry deposition of nitrogen dioxide, ozone, carbon monoxide, acid gases, and particulate matter (Tyrvainen *et al*., 2005; McDonald *et al*., 2007; Fowler *et al*., 2009) but some trees also produce significant quantities of volatile organic compounds (VOCs), particularly isoprene, which can take part in atmospheric photochemistry to produce ozone and particulate matter (MacKenzie *et al*., 1991). We used air quality modelling and existing air quality standards to quantify the balance between these positive and negative effects of trees on air quality, for a UK West Midlands case study (Donovan *et al*., 2005). Running the air quality model with and without enhanced tree cover produced changes to simulated atmospheric composition which were then compared to air quality standards to produce an urban tree air quality score (UTAQS):

$$\text{UTASQS} = -100\left(\frac{\Delta O_3}{AQS_{O3}} + \frac{\Delta NO_2}{AQS_{NO2}} + \frac{\Delta HNO_3}{AQS_{PM10}}\right)$$

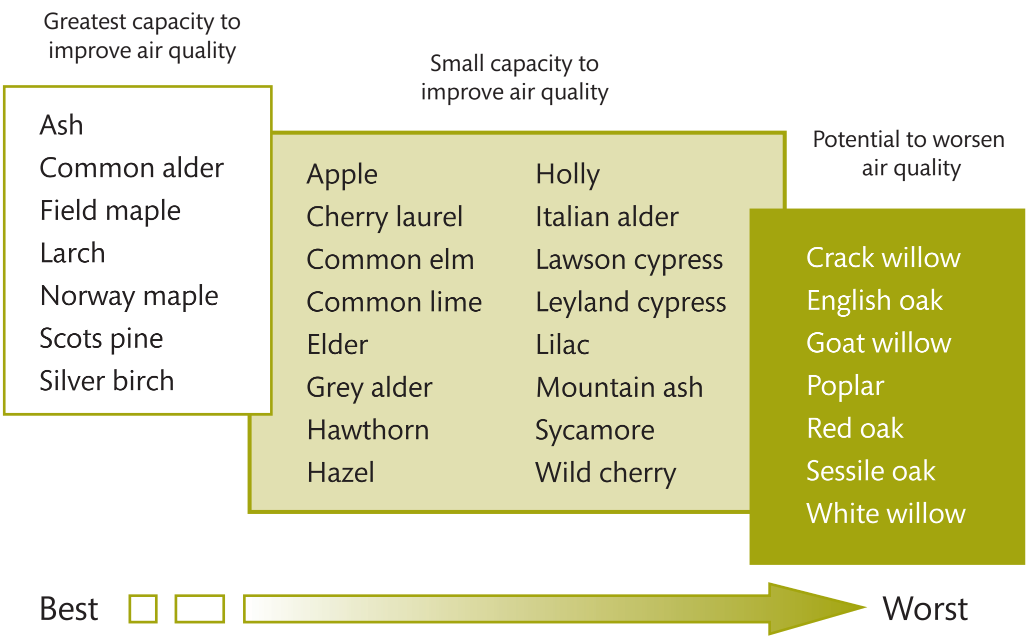
where $\Delta O_3$ is the difference between the UTAQS model run and the control run, in the peak 8-hour running mean concentration of $O_3$ on the fifth day; $\Delta NO_2$ is the difference in the peak 1-hour concentration of $NO_2$ on the fifth day; $\Delta HNO_3$ is the difference in the modelled 24-hour running mean of $HNO_3$ on the fifth day (in $\mu g\ m^{-3}$); and $AQS_{O3}$, $AQS_{NO2}$, and $AQS_{PM10}$ are the air quality standards for $O_3$ (50 ppb), $NO_2$ (150 ppb), and PM10 (50 µg $m^{-3}$), respectively. The values are multiplied by -100 to give a positive value for an improvement in air quality when compared to the control tree population and to scale UTAQS scores to be between -10 and +10. From this model study, which was built on intensive survey work (Donovan *et al*., 2010), land use classification (Owen *et al*., 2006), and laboratory and field studies of VOC emissions from trees (Owen *et al*., 2003; Stewart *et al*., 2003), we were able to produce 'traffic light' guidance for the impact of tree species on air quality (Figure 1).

The implication is that our native oaks, willows, and poplars could be detrimental to air quality for the conditions modelled (stagnant, summer-time, anticyclonic conditions). Of course, one should not forget that native trees have very high year-round ecological and aesthetic value and there is much to be said in favour of a comprehensive, rather than partial, cost-benefit analysis. Our point is that, if large-scale tree planting schemes are to be used specifically to enhance air quality, then species with low-ranking UTAQS should be avoided. We discuss limitations of the Donovan *et al*. (2005) study in the next section.

As well as providing surfaces for dry deposition, and emitting VOCs, urban trees and green spaces can affect the dispersion of air pollutants by affecting wind flow. Urban green space will not, in general, have the same aerodynamic roughness as the surrounding built environment (Oke, 1989) and so will change wind speeds by providing a larger or smaller sink for atmospheric momentum. Urban green space also interacts differently with incoming solar energy; the built environment gives rise to the well-known urban heat island (Oke, 1973), which is ameliorated by urban green space (Oke, 1989). The effect of green space is visible at the city scale (Tyrvainen *et al*., 2005). There are also important local effects. Air flow in street canyons depends on the wind speed, wind direction, and canyon geometry (Salmond and McKendry, 2009; Llewellyn Davies for English Partnerships with Commission for Architecture and the Built Environment and the Housing Corporation, 2000). For canyon height-to-width ratios above about 0.7, internal circulations are set up in the canyons, cut-off, except by turbulent mixing, from the flow above, which skims over the urban landscape (Oke, 1988; Xie *et al*., 2005). Street trees can exacerbate the decoupling of canyon air from the skimming flow above, increasing street-level pollution in streets with a ground-level source such as traffic (Buccolieri *et al*., 2009).

Before describing how futures scenarios can help assess the resilience of a proposed solution, it is worth noting that some proposed solutions do not pass the pre-requisite of being fit-for-purpose now. For example, in 2005, a local council in London constructed a green wall, believed to be the first of its type in the UK. Within four years the rainwater watering system had failed and the living wall died (http://news.bbc.co.uk/1/hi/england/london/8215035.stm).

**Figure 1** The potential for trees of a given species to impact urban air quality, based on model simulations for the West Midlands, UK (adapted from Donovan *et al*., 2005).

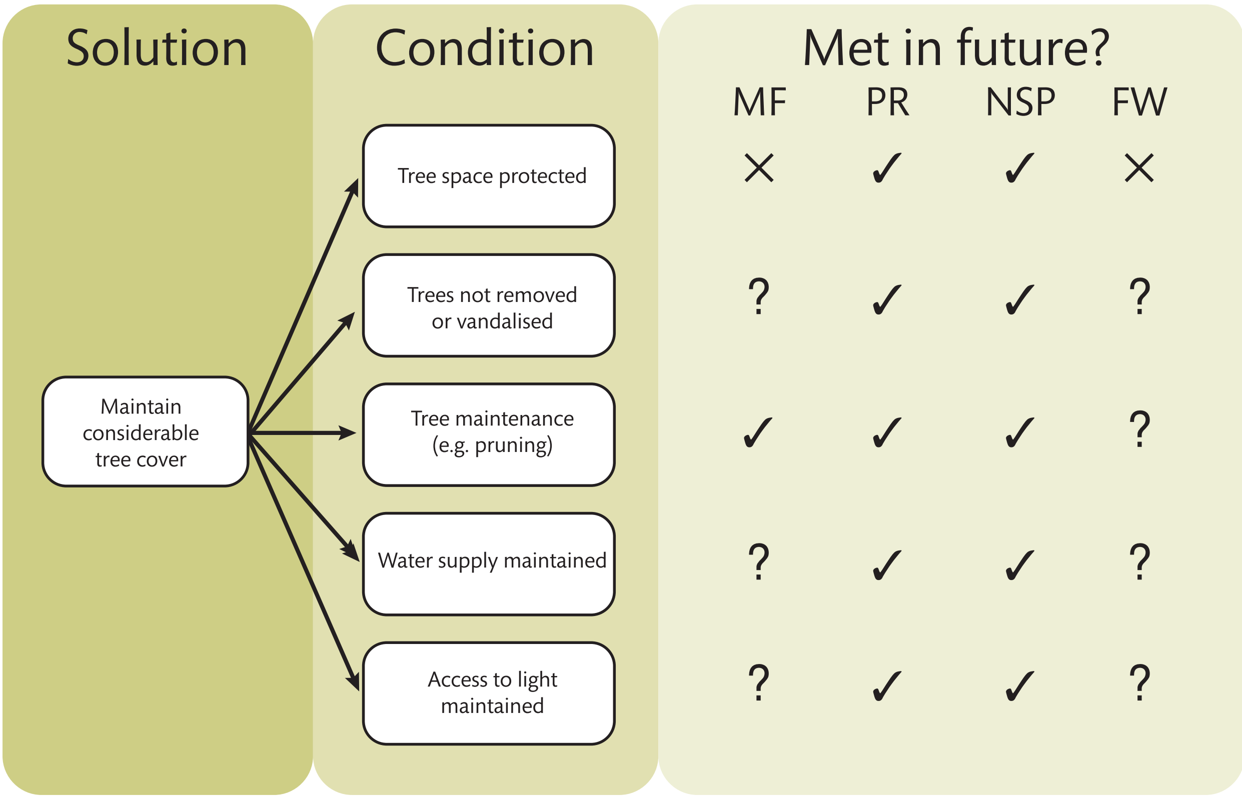


Although a laudable effort, and although clearly the risks for early adopters are greater than for those following behind, local conditions must be capable of sustaining a solution if it is to be implemented successfully.

Having established that a proposed solution is fit-for-purpose under the current conditions pertaining to a particular site, futures scenarios can then be used as 'test rigs' to assess the resilience of a solution in the face of change. Figure 2 shows the necessary conditions for the sustainability solution 'maintaining considerable tree cover'. This particular analysis is for a recent case study in Lancaster, UK; we choose to discuss this example here because it relates to urban vegetation and because, once the present fitness-for-purpose has been established in this particular location, the results are not case-study specific. By analysing the scenario characteristics it has been determined whether or not these conditions are met in each of the four Urban Futures scenarios. For instance, the first condition is that tree space is protected in the future. This condition is met in both the PR and NSP scenarios where strong planning controls are applied which recognise ecological and social imperatives. However, in the MF scenario, planning policy is weak, and enforcement of that policy favours the power of the market, meaning that tree space will not be protected if it is wanted for some more profitable use. In the FW scenario trees may be valued by the wealthy, but planning policy does not extend much past the priority issues of resource protection.

Figure 2 can be read in different ways. Reading across the figure provides guidance on which conditions, necessary for the sustainability solution, are most at risk of ceasing to be met. Reading down the columns in the right-most panel makes clear which futures scenario carries the most risk for the solution and, hence, which drivers and characteristics, embodied in the futures, should be targeted to try to avoid failure. It may seem self-evident that the 'rosy' futures provide the most positive outcomes, but this is not always the case. Hunt *et al*. (2011) provide an example in which grey-water recycling schemes become obsolete in the NSP scenario because of behavioural change; from a futures perspective, sustainability solutions which depend on the continuation of current consumer behaviour have obsolescence built in. Note that neither the UTAQS nor the solution examined in Figure 2 capture the importance of tree cover topology, as discussed briefly above with respect to bat boxes.

**Figure 2** Necessary conditions for the continuing operation of the sustainability solution 'maintaining considerable tree cover', for a case study in Lancaster, UK. The likelihood that each necessary condition will continue to be met in each future scenario is assessed in the right-most panel. A tick denotes that there is a high likelihood of the condition being met; a cross denotes that there is a high likelihood of the condition not being met. Ambiguous or uncertain assessments are denoted by a question mark. Some of the rationale behind the assessments is given in the main text.



## Limitations

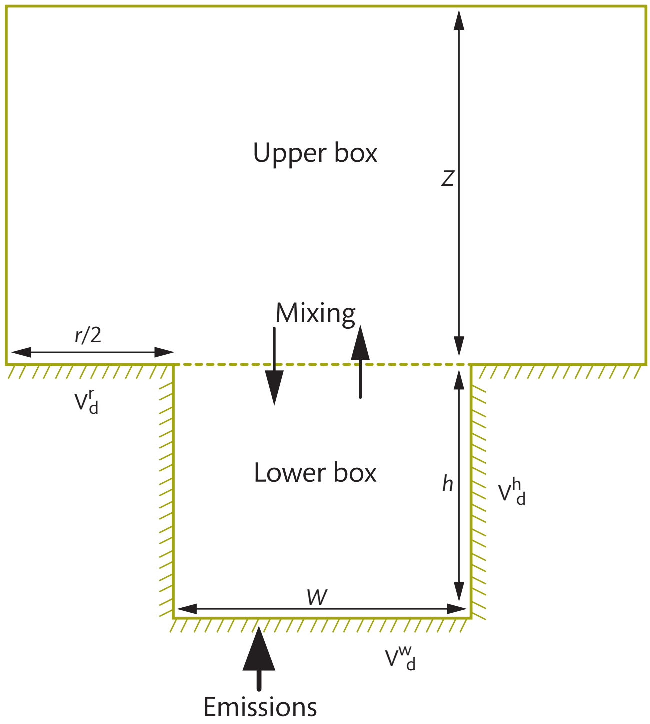
There are limitations in our method for establishing the resilience of sustainability solutions. Broadly, the limitations fall into three categories: the futures space exercised in our scenario 'test rigs'; limits to knowledge in discipline-specific assessments; and difficulties in multi-disciplinary working.

Our chosen scenarios cannot cover all eventualities. Four scenarios have been chosen that cover a wide range of possible futures for which there is extensive literature. The existence of an extensive literature, including detailed quantitative and qualitative indicators, for each scenario is useful to us, because it provides an audit trail for our derivation of the UK urban characteristics. Nevertheless, it is quite possible to derive urban futures from first principles and to then use these to test the resilience of solutions. It also possible, and more straightforward, to add characteristics to our existing UK urban futures, in order to cover aspects of urban living not considered by the Urban Futures project. This is discussed further in Boyko *et al*. (2011).

No discipline-based assessment is final. The provisional nature of any discipline-based assessment can be one of the factors that make multi-disciplinary work difficult. Multi-disciplinary work shares this problem with public understanding of science and with the provision of scientific advice to policy-makers. Best practice in multi-disciplinary collaboration will likely closely mirror best practice in these areas of knowledge exchange (People Science and Policy Ltd, 2003).

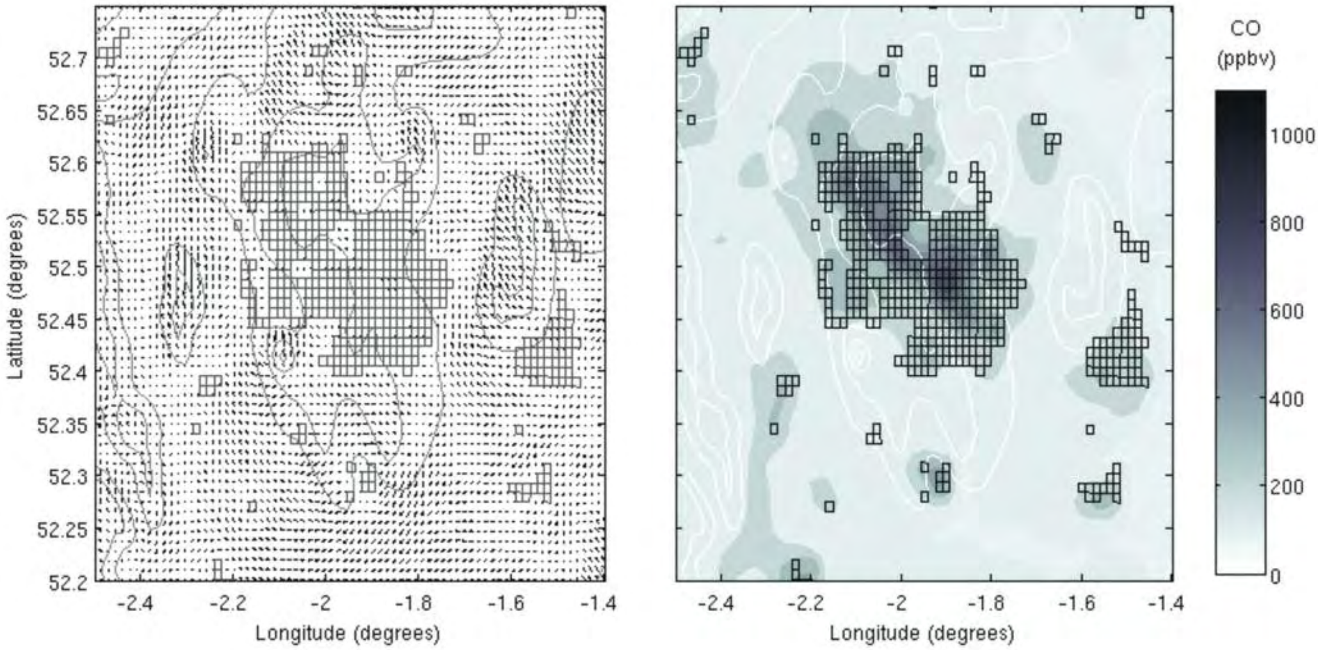
As our disciplinary knowledge expands and assessment tools are refined, assessments can become increasingly sophisticated. For instance, the model used in the UTAQS study describe in the previous section has been updated (Pugh *et al*., 2011) to include a new scheme for the photo-oxidation of isoprene (Taraborrelli *et al*., 2009) and is now being set up to simulate the air inside and above urban street canyons (Figure 3). We expect that this new model configuration will more accurately account for time traffic emissions spend within the urban canopy before being vented into the atmospheric boundary layer above (see, e.g., Oke and Cleugh, 1987, for descriptions and definitions of the urban canopy and the atmospheric boundary layer, or Llewellyn Davies for English Partnerships with Commission for Architecture and the Built Environment and the Housing Corporation, 2000, for a very brief overview). Even then, this air quality model will not represent the horizontal heterogeneity of urban landscapes. To represent this heterogeneity, a three-dimensional mesoscale model is required (Zhang *et al*., 2009; Zou *et al*., 2009). Figure 4 shows an example of three-dimensional urban air quality modelling from the work that is currently under way as part of the Urban Futures project. Again using the West Midlands, UK as a case study, the model shown incorporates an urban surface scheme with spatially varying aerodynamic roughness elements that protrude into the model atmosphere (rather than providing a boundary condition for the lowest atmospheric layer only). The result is a highly heterogeneous wind field, with a concomitant effect on the dispersion of air pollutants such as carbon monoxide.

**Figure 3** Schematic diagram of the modification of the CiTTyCAT air quality model to incorporate street canyon effects. The upper box simulates the well-mixed atmospheric boundary layer, depth, z, where 100 < z < 1500 m, typically. The lower box simulates a well-mixed street canyon of height, h (typically 10 m), and width, w (0.5 < height:width < 2, typically). The ratio w/r specifies the density of canyons in the urban fabric. Turbulent mixing between the boxes is modelled using an exchange rate calculated in computational fluid dynamics studies (Liu *et al*., 2005). Deposition of pollutants can be to the canyon walls, with deposition velocity $V^{w}d$, canyon floor ($V^{w}d$), or to the roofs ($V^{r}d$). These deposition velocities can be modified from default values for building materials to simulate installation of green walls and roofs.




A detailed critical assessment of the multi-disciplinarity in the Urban Futures project is outside the scope of this discussion, but some remarks are appropriate, since implicit in everything preceding is the requirement to assess solutions simultaneously from as many perspectives as possible (MacKenzie *et al*., 2010). In the Urban Futures project, we have enacted a 'talking cure' for the problems of multi-disciplinary work: project researchers have met monthly and, at times, more frequently. Project-wide tasks

Figure 4 Example output for the WRF/CHEM three-dimensional mesoscale model, run at 1-km horizontal resolution over the West Midlands, UK, for the sunny anticyclonic period 15–19 July 2006. Results shown are for at 04:00 UT on 18/07/06. The hatched areas are urban (Birmingham is near the centre of the picture and Coventry on the right-hand edge). Contours are height above sea level at 50-m intervals. Left panel: 10-m wind arrows showing deceleration over the urban area. Right panel: surface-level carbon monoxide (CO) mixing ratios (parts-per-billion by volume, ppbv). CO emissions originate predominantly from urban traffic emissions and disperse downwind.




have been set, and tackled alongside an extensive discipline-based research programme across natural and social science. Issues regarding methodology and terminology have been accommodated, and project-wide tasks progressed, in the frequent researcher meetings. By focusing on multi-disciplinary tasks in researcher meetings, and by refusing to allocate multi-disciplinary aspects of the programme to 'multi-disciplinarity specialists', we have avoided bolting an ill-fitting multi-disciplinary superstructure onto the disciplinary research programme. Meeting and talking can make progress seem slow. Concepts in sustainability are notoriously slippery and it can often feel as if ground has to be covered and re-covered. Nevertheless, we argue, as do others, that this dialogue and team-working, however tortuous it may sometimes appear, is an essential part of the kind of multi-disciplinary work that will yield progress on grand challenges such as sustainable urban development (see input to the SUE Research Dialogues Workshop, available at http://suedialogues.wordpress.com/events/the-workshop/). In passing, we observe that, in our experience, tools for virtual meetings are not yet sufficiently robust to replace face-to-face meetings and so, in this respect, our own project has not reached best practice in terms of decarbonisation.

## Conclusions

Sustainability, regardless of which definition is chosen, is all about putting in place now sustainability solutions that will yield positive rather than negative future legacies. The essential underlying question is 'how sustainable are these solutions?' The answer is inevitably 'it depends on local conditions now and in the future'. At present, our approach to implementing solutions is very front-loaded; most of the funding, research, planning, publicity, and policy enforcement occur when a solution is installed. We have described above a method to assess whether a solution will continue to yield benefits for a very wide range of possible futures.

That we note in passing the potential for sustainable solutions to fail in the here-and-now suggests that the best practice of designing solutions to fit local conditions is not yet being achieved routinely. Uncritical adoption of solutions — rainwater recycling, green roofs, etc. — might be a result of successful advocacy by academics, non-governmental organisations, and activists. Such simple advocacy of urban greening may be appropriate in policy debates, but is of limited use when trying to ensure best practice. Assessing the sustainability of a solution requires a critical and multi-disciplinary approach with due regard for local conditions. It is because multi-disciplinary team-working is not always practicable that we have developed the Urban Futures method and its attendant materials.

The disciplinary knowledge used in sustainability assessments is perforce provisional. We have discussed how the assessment of the impacts of urban trees on air quality is model dependent, and set out recent advances in the modelling of urban areas that may affect the assessment.

The Urban Futures method makes use of established future scenarios. It is no accident that some of the futures appear better than others. The GSG scenarios are not morally, ethically, or politically neutral; they explicitly extend current tendencies – dominant or not – to generate a range of outcomes, and so make it clear what must be done to ensure an outcome that is favourable in the authors' terms. All futures research is underpinned by this utopianism or, at the very least, by a recognition that talking about the future alters it (Bell, 1996), which, along with the ability to incorporate tipping points, differentiates futures research from conventional extrapolation studies. For the GSG authors, their studies make evident the need for a 'great transition' towards sustainability (Raskin *et al*., 2002). Urban Futures is not so directly utopian in its use of futures; we use scenarios as 'test rigs' that exercise solutions in a very wide range of future conditions. Nevertheless, as a tool for policy-making, the Urban Futures method can show which solutions have the best chance of continuing to work into the future and, hence, of bringing about the move to sustainability that policy seeks.

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## References

BEATLEY, T. (2010). *Biophilic Cities: Integrating Nature Into Urban Design and Planning.* Island Press, Washington D.C.

BELL, W. (1996). What do we mean by future studies? *In:* Slaughter, R. (ed.) *New thinking for a new millennium.* Routledge, London, pp. 3–25.

BOYKO, C.T., GATERELL, M.R., BARBER, A.R.G., BROWN, J., BRYSON, J.R., BUTLER, D., CAPUTO, S., CASERIO, M., COLES, R., COOPER, R., DAVIES, G., FARMANI, R., HALE, J., HALES, A.C., HEWITT, C.N., HUNT, D.V.L., JANKOVIC, L., JEFFERSON, I., LEACH, J.M., LOMBARDI, D.R., MACKENZIE, A.R., MEMON, F.A., PUGH, T.A.M., SADLER, J.P., WEINGAERTNER, C., WHYATT, J.D. AND ROGERS, C.D.F. (2011). Benchmarking sustainability in cities: The role of indicators and future scenarios. *Global Environmental Change* doi:10.1016/j.gloenvcha.2011.10.004.

BUCCOLIERI, R., GROMKE, C., DI SABATINO, S. AND RUCK, B. (2009). Aerodynamic effects of trees on pollutant concentration in street canyons. *Science of the Total Environment* **407**, 5247–5256.

DONOVAN, R., OWEN, S., HEWITT, C.N., MACKENZIE, A.R. AND BRETT, H. (2010). *The Development of an Urban Tree Air Quality Score (UTAQS): using the West Midlands, UK Conurbation as a Case Study Area*, VDM Verlag Dr. Müller, Dordrecht.

DONOVAN, R.G., STEWART, H.E., OWEN, S.M., MACKENZIE, A.R. AND HEWITT, C.N. (2005). Development and application of an urban tree air quality score for photochemical pollution episodes using the Birmingham, United Kingdom, area as a case study. *Environmental Science and Technology* **39**, 6730–6738.

DROEGE, P. (2006). *The Renewable City.* John Wiley and Sons Ltd, Chichester.

FISCHER-KOWALSKI, M. AND HALBERL, H. (2007). *Socioecological Transitions and Global Change,* Edward Elgar.

FOWLER, D., PILEGAARD, K., SUTTON, M.A., AMBUS, P., RAIVONEN, M., DUYZER, J., SIMPSON, D., FAGERLI, H., FUZZI, S., SCHJOERRING, J.K., GRANIER, C., NEFTEL, A., ISAKSEN, I.S.A., LAJ, P., MAIONE, M., MONKS, P.S., BURKHARDT, J., DAEMMGEN, U., NEIRYNCK, J., PERSONNE, E., WICHINK-KRUIT, R., BUTTERBACH-BAHL, K., FLECHARD, C., TUOVINEN, J.P., COYLE, M., GEROSA, G., LOUBET, B., ALTIMIR, N., GRUENHAGE, L., AMMANN, C., CIESLIK, S., PAOLETTI, E., MIKKELSEN, T.N., RO-POULSEN, H., CELLIER, P., CAPE, J.N., HORVATH, L., LORETO, F., NIINEMETS, U., PALMER, P.I., RINNE, J., MISZTAL, P., NEMITZ, E., NILSSON, D., PRYOR, S., GALLAGHER, M.W., VESALA, T., SKIBA, U., BRUEGGEMANN, N., ZECHMEISTER-BOLTENSTERN, S., WILLIAMS, J., O'DOWD, C., FACCHINI, M.C., DE LEEUW, G., FLOSSMAN, A., CHAUMERLIAC, N. AND ERISMAN, J.W. (2009). Atmospheric composition change: ecosystems-atmosphere interactions. *Atmospheric Environment* **43**, 5193–5267.

GALLOPIN, G., HAMMOND, A., RASKIN, P.A. AND SWART, R. (1997). *Branch Points: Global Scenarios and Human Choice.* Stockholm Environment Institute.

GEHL, J. (2010). *Cities for People.* Island Press, Washington, D.C.

HARNIK, P. AND BLOOMBERG, M.M. (2010). *Urban Green: Innovative Parks for Resurgent Cities.* Island Press, Washington D.C.

HOLLANDER, J.B., KIRKWOOD, N.G. AND GOLD, J.L. (2010). *Principles of Brownfield Regeneration,* Island Press, Washington, D.C.

HUANG, C.D., SHAO, Y., LIU, J.H. AND CHEN, J.S. (2007). Temporal analysis of urban forest in Beijing using Landsat imagery. *Journal of Applied Remote Sensing* **1**, 013534, DOI: 10.1117/1.2794001.

HUNT, D., LOMBARDI, R., ATKINSON, S., BARBER, A., BARNES, M., BOYKO, C., BROWN, J., BRYSON, J., BUTLER, D., CAPUTO, S., CASERIO, M., COLES, R., FARMANI, R., GATERELL, M., HALE, J., HAYES, C., HEWITT, N., JANKOVIC, L., JEFFERSON, I., MACKENZIE, R., MEMON, F., PUGH, T.A.M., ROGERS, C., WHYATT, D. AND WEINGARTNER, C. (2011). Scenario Archetypes: Converging rather than Diverging Themes. *In: Proceedings of the 1st World Sustainability Forum*, 1-30 November 2011, Sciforum Electronic Conferences Series. [Online] Available at: http://www.sciforum.net/presentation/720.

LIU, C.H., LEUNG, D.Y.C. AND BARTH, M.C. (2005). On the prediction of air and pollutant exchange rates in street canyons of different aspect ratios using large-eddy simulation. *Atmospheric Environment* **39**, 1567–1574.

LLEWELLYN DAVIES FOR ENGLISH PARTNERSHIPS WITH COMMISSION FOR ARCHITECTURE AND THE BUILT ENVIRONMENT AND THE HOUSING CORPORATION (2000). *Urban Design Compendium,* London.

MCDONALD, A.G., BEALEY, W.J., FOWLER, D., DRAGOSITS, U., SKIBA, U., SMITH, R.I., DONOVAN, R.G., BRETT, H.E., HEWITT, C.N. AND NEMITZ, E. (2007). Quantifying the effect of urban tree planting on concentrations and depositions of PM10 in two UK conurbations. *Atmospheric Environment* **41**, 8455–8467.

MACKENZIE, A.R., HARRISON, R.M., COLBECK, I. AND HEWITT, C.N. (1991). The role of biogenic hydrocarbons in the production of ozone in urban plumes in Southeast England. *Atmospheric Environment Part A-General Topics* **25**, 351–359.

MACKENZIE, A.R., PUGH, T.A.M. AND ROGERS, C.D.F. (2010). Sustainable Cities: seeing past the trees. *Nature* **468**, p765.

OKE, T.R. (1973). City size and urban heat island. *Atmospheric Environment* **7**, 769–779.

OKE, T.R. (1988). Street design and urban canopy layer climate. *Energy and Buildings* **11**, 103–113.

OKE, T.R. (1989). The micrometeorology of the urban forest. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* **324**, 335–349.

OKE, T.R. AND CLEUGH, H.A. (1987). Urban heat-storage derived as energy-balance residuals. *Boundary-Layer Meteorology* **39**, 233–245.

OWEN, S.M., MACKENZIE, A.R., BUNCE, R.G.H., STEWART, H.E., DONOVAN, R.G., STARK, G. AND HEWITT, C.N. (2006). Urban land classification and its uncertainties using principal component and cluster analyses: A case study for the UK West Midlands. *Landscape and Urban Planning* **78**, 311–321.

OWEN, S.M., MACKENZIE, A.R., STEWART, H., DONOVAN, R. AND HEWITT, C.N. (2003). Biogenic volatile organic compound (VOC) emission estimates from an urban tree canopy. *Ecological Applications* **13**, 927–938.

PEOPLE SCIENCE AND POLICY LTD (2003). *Partnerships for Public Awareness: Good Practice Guide*. Engineering and Physical Sciences Research Council, Swindon.

PUGH, T.A.M., CAIN, M., METHVEN, J., WILD, O., ARNOLD, S., REAL, E., EMMERSON, K.E., OWEN, S.M., HEWITT, C.N. AND MACKENZIE, A.R. (2011). A Lagrangian model of air-mass photochemistry and mixing using a trajectory ensemble: The Cambridge Tropospheric Trajectory model of Chemistry And Transport (CiTTyCAT). *Geoscientific Model Development* **4**, 2469-2544.

RASKIN, P., BANURI, T., GALLOPIN, G., GUTMAN, P., HAMMOND, A., KATES, R.A. AND SWART, R. (2002). *Great Transitions: The Promise and Lure of the Times Ahead*. Stockholm Environment Institute.

RASKIN, P., GALLOPIN, G., GUTMAN, P., HAMMOND, A.A. AND SWART, R. (1998). *Bending the Curve: Toward Global Sustainability.* Stockholm Environment Institute.

ROGER EVANS ASSOCIATES, ENGLISH PARTNERSHIPS AND THE HOUSING CORPORATION (2007). *Urban design compendium 2: Delivering quality places.* English Partnerships, London.

SALMOND, J. AND MCKENDRY, I. (2009). Influences of meteorology on air pollution concentrations and processes in urban areas. *In:* Hester, R. and Harrison, R.M. (eds.) *Air Quality in Urban Environments.* Royal Society of Chemistry Publishing, Cambridge, UK, pp. 23–41.

SAMET, R.H. (2008). *Long-range Futures Research – an Application of Complexity Science.* Booksurge Publishing, North Charleston, South Carolina.

SLAUGHTER, R.A. (1995). *The Foresight Principle*. Adamantine Press.

STEWART, H.E., HEWITT, C.N., BUNCE, R.G.H., STEINBRECHER, R., SMIATEK, G. AND SCHOENEMEYER, T. (2003). A highly spatially and temporally resolved inventory for biogenic isoprene and monoterpene emissions: Model description and application to Great Britain. *Journal of Geophysical Research-Atmospheres,* 108. DOI: 10.1029/2002JD002694.

SUZUKI, H., DASTUR, A., MOFFATT, S., YABUKI, N. AND MARUYAMA, H. (2010). *Eco2 Cities: Ecological cities as economic cities.* World Bank Publications, Washington, D.C.

TARABORRELLI, D., LAWRENCE, M.G., BUTLER, T.M., SANDER, R. AND LELIEVELD, J. (2009). Mainz Isoprene

Mechanism 2 (MIM2): an isoprene oxidation mechanism for regional and global atmospheric modelling. *Atmospheric Chemistry and Physics* **9**, 2751–2777.

TYRVAINEN, L., PAULEIT, S., SEELAND, K. AND DE VRIES, S. (2005). Benefits and uses of urban forests and trees. *In:* Konijnendijk, C.C., Nilsson, K., Randrup, T.B. and Schipperijn, J. (eds.) *Urban Forests and Trees.* Springer-Verlag, Heidelberg.

XIE, X.M., HUANG, Z., WANG, J.S. AND XIE, Z. (2005). The impact of solar radiation and street layout on pollutant dispersion in street canyon. *Building and Environment* **40**, 201–212.

ZHANG, D.L., SHOU, Y.X. AND DICKERSON, R.R. (2009). Upstream urbanization exacerbates urban heat island effects. *Geophysical Research Letters,* **36**, DOI: 10.1029/2009GL041082.

ZOU, B., WILSON, J.G., ZHAN, F.B. AND ZENG, Y.N. (2009). Spatially differentiated and source-specific population exposure to ambient urban air pollution. *Atmospheric Environment* **43**, 3981–3988.

# Community participation in urban tree cover in the UK


## Abstract

A greater emphasis on community participation in local decision making in the UK has been evident both from the previous and current governments and is a central theme of the 'Big Society', based on notions of personal responsibility and a shrinking state.

This paper reviews community participation in urban tree cover. How is community defined and what does participation mean? Communities can represent both geographical areas and well as interest groups, while participation can involve a range of levels and ways of engagement. Why encourage participation? Is it in order to legitimise and overcome barriers to project implementation, or for more intrinsic reasons linked to empowerment and the generation of social capital?

Will the withdrawal of central government and an emphasis on civic society leave a gap in supporting the delivery of high quality tree cover? What is the role of external agencies in promoting and supporting community participation and community action?

New media – digital communications represented by the internet, blogs, and social network sites – have created new opportunities for people to participate in a range of issues including urban tree cover. What questions does this raise for governance and representation? Do new media encourage genuine participation? How can communities influence tree and woodland cover where this impacts on their communities?

This paper will review experience and evidence from a range of projects and research, and suggest areas for further study.


## Introduction

Recent years have seen increasing emphasis on community participation within political rhetoric, as a way of identifying, shaping and delivering policy across government (Burton *et al*., 2004; Miliband, 2006; Cameron, 2010; Clark, 2010; Norman, 2010). This coincides with a greater devolution of decision making and power from UK Government to national and local government, and to communities and individuals (DCLG, 2008, 2010).

Within the urban environment there has been a move from consultation which serves a public interest to a greater degree of active communication, knowledge exchange and development of ideas with stakeholders (Van Herzele *et al*., 2005). This reflects notions of active citizenship, development of social capital and participatory democracy which are built into the idea of the Big Society.

Urban tree cover and urban forestry have developed and become distinct within forestry more generally as urban society and conurbations have expanded. The focus on social and environmental objectives and the proximity to large numbers of people leads to a demand for varying levels of communication and involvement in decisions about urban tree cover (Konijnendijk, 2000). Urban trees often evoke strong emotional ties and reactions, particularly where changes to tree cover are planned.


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## Defining community

Notions of 'community' and 'community participation' are built into many areas of government. Definitions are more elusive. In a report for the Department for Communities and Local Government, Pratchett *et al*. (2010) define 'community' as a group 'that recognise that they have something in common with each other, or who are recognised by others as such'.

Communities may be defined geographically, by their interests, by the services they use, by gender, ethnicity, religion, and so on (Smith, 2001). For instance, Asian women have often been identified as a community with an interest in using public open spaces but who may be prevented due to concerns over abuse and therefore excluded from participation in urban woods (Risbeth, 2004). Moore (2003) describes disabled, retired, black and minority ethnic communities, those aged 45–64 years, women and those from the more deprived social groups as under-represented users of green space – communities within a geographical community.

The diversity of communities needs to be recognised and was one of the key lessons of a report for the Home Office on the effectiveness of community involvement in area-based initiatives (Burton *et al*., 2004).

## Defining participation

Definitions of participation are contested. Typologies of participation identify passive participation, where people are informed of what will happen, through to self-mobilisation, where communities initiated action independently of external agencies (Rifkin and Kangere, 2002; UNESCAP, 2009).

The National Community Forum defines community participation as taking place where statutory bodies and communities work in partnership to develop and/or implement policy (Morris, 2006). Cheetham (2002) identifies community participation as 'when a community organises itself and takes responsibility for managing its problems...[including]...identifying the problems, developing actions, putting them into place, and following through.'

Participation can be defined as the process and active involvement of stakeholders in the formulation of policies and strategies and in their analysis, planning, implementation, monitoring and evaluation. Community participation means some form of involvement of people, with similar needs and goals, in decisions affecting their lives.

## Defining empowerment

Most definitions of empowerment refer to the ability of an individual, organisation or community to gain power and control over decisions and resources to bring about positive change. It has been defined as 'passing more and more political power to more and more people by whatever practical means available' (DCLG, 2009).

Beyond influencing decisions taken by others in authority it can also be seen as increasing autonomy and self-reliance (Eames *et al*., 2009). This is indicated through an increase in social capital – communities developing confidence in their ability and capacities, increased skills, greater resources and the development of networks of contacts. The idea of empowerment is often directed towards those who are excluded from decision-making processes through disadvantage or discrimination.

During the 1980s, Balsall Heath in Birmingham became associated with crime and prostitution; it was an area run down and in decay. Over 25 years the Balsall Heath Forum, made up of over 1000 members of the local community, have campaigned and taken action to improve the area, transforming it into a green and welcoming community. The Forum now acts as the local representation to the public and private sectors (Balsall Heath Forum, 2011). Through taking action to improve their local environment and reduce crime, the community is reported to have grown in confidence with increasing community 'togetherness'.

## Empowering and empowerment

It is possible to distinguish between empowering and empowerment. People or organisations that are 'empowering' are able to facilitate an individual or group to take control of the knowledge or resources needed to bring about positive change. Those who are 'empowered' can develop and master that knowledge or resources to make positive change for themselves and for others. Ideas of participation and empowerment are closely associated. Active participation requires a degree of empowerment – confidence, knowledge, resources – while participation can itself be seen to as part of a process of empowerment (Perkins and Zimmerman, 1995).

This is an important distinction when considering the role of third parties, such as public bodies and non-governmental organisations, in fostering empowerment and participation, while not excluding the possibility that individuals from within a community can be empowering.

Pepper Wood Community Woodland owned by the Woodland Trust was set up in the early 1980s. The group has been going for 25 years and actively manages the wood for a range of coppice and other products (Woodland Trust, 2011a). The Trust overcame the barriers to establishment of the group through providing a suitable site and through developing the governance and skills the group needed to get started and to establish their own systems for recruiting new members, training and management.

## Why encourage participation?

Motivations for government, non-governmental organisations and others for encouraging participation differ. Participation can be used instrumentally to improve project outcomes, remove or ease conflict, increase acceptance, and achieve greater sustainability of the project. This can be seen in examples of involving local youth in tree planting projects or woodland management in the expectation of reducing vandalism (Barker and Bridgeman, 1994; Woodland Trust, 2002; Basingstoke and Deane Borough Council, 2011).

Alternatively participation can be viewed as a way of empowering people and communities, building social capital and redistributing power from central authorities to communities; participation as an end in itself, rather than a means to an end (UNESCAP, 2009). The Green Streets programme in Manchester, while delivering instrumental benefits in the form of street tree planting, also aims to 'encourage community interaction and improve community spirit...fostering a sense of ownership in communities and empowering them to change their neighbourhoods for the better' (Red Rose Forest, 2010).

In the past the emphasis of 'community woodland' has frequently been on the creation of 'woodland' which involved, at various levels, the community. Participation was a means to an end in the creation or management of woodland or in conflict resolution.

A review of community involvement by Burton *et al.* (2004) identified a mix of instrumental and intrinsic motivations of government in involving the community:

- aiding social cohesion through its effect on individuals and society, and fostering social capital;
- effective planning and delivery of services and legitimacy of decisions;
- as a right of citizenship justified on the grounds of due process, irrespective of outcome.

The Transition Town movement also demonstrates a more empowered approach; for instance using public space to plant nut and fruit-bearing trees (Transition Town Totnes, 2011). More radically, Guerrilla Gardening encourages planting of trees on public space without consent (Guerrilla Gardening, 2011). There is an opportunity to reframe the emphasis on 'community', so that participating in woodland becomes a way in which individuals and communities can develop and in which social capital can be increased.

## Benefits of participation in urban tree cover

There is a growing body of evidence to suggest even a passive experience of a 'green' environment has a positive effect on physical and mental health, and can have beneficial social impacts such as reduced driving frustration and aggression, and less reported crime and domestic violence (Kuo and Sullivan, 1996, 2001; Kuo, 2003).

Active involvement, including volunteering for tree planting and maintenance, engaging with planning and design, or campaigning to protect trees, can confer further benefits through improved health as a result of a more active lifestyle or through increased social capital (Westphal, 2003; Townsend, 2006). These benefits can accrue to the individual, an organisation or the community.

The Cydcoed project in Wales, delivered through the Forestry Commission Wales, funded community groups who wanted to plant new woods or manage existing ones in their area. Evaluation of the project suggested that 80% of the 163 groups felt that their project had helped develop stronger ties within their community, and more than 50% of interviewees felt involvement had improved their overall health and wellbeing (Forestry Commission, 2008).

The relative ease of participation with urban trees, compared to other social problems such as tackling unemployment or drug abuse, can provide communities with a starting point which leads to tackling more difficult issues (Westphal, 1999). Empowerment of the individual through active participation in social change has wider benefits in the organisation and creation of communities (Sadan, 2004).

## New media

New media refers to electronic communication made possible through the use of computer technology, as opposed to old media, such as print newspapers and magazines. It includes websites, chat rooms, email, online communities, digital cameras and mobile computing. New media can be seen as offering new and novel opportunities for participation and for generating a greater participatory culture (Friedman, 2010). New media have supported the emergence of social phenomena such as blogs and social networking, and have allowed almost instant access and exchange of information and the opportunity for individuals to generate and post web content.

Bristol Street Trees was established in 2006 as a result of concern among a group of residents at the loss of urban trees. They put up a website and began to collect pictures of the stumps of felled trees to illustrate the loss of tree cover and to lobby the local council. The website attracted local and national media coverage and has resulted in Bristol City Council setting up a Tree Forum to address some of the issue of tree loss and to replace felled trees (Bristol Street Trees, 2009).

## Transmedia

There is also increasing interest in 'transmedia' as a form of storytelling or conveying information in an interactive way. Originally designed for use in entertainment and marketing, transmedia storytelling allows people to follow a story or issue across a range of media with varying levels of engagement and participation (Srivastava, 2009). It appeals in particular to a younger generation who regularly and consistently use a range of media including gaming. Transmedia creates a narrative which allows participants to interact with the story and thus generates actions for social change.

## Rapid mobilisation

Websites such as Flickr, Wikipedia and Facebook encourage the submission of content to the internet. Social network sites create opportunities to connect with others, recruit volunteers and increase individual-level production of social capital. They have the power to enable very rapid mobilisation of campaigners and activists, for example the '38 Degrees' campaign against disposal of the Public Forest Estate in England (38 Degrees, 2011).

Furthermore, the cost associated with organising members and meetings, and spreading and collecting information, is relatively low compared to more traditional forms of social organisation (Ellison *et al*., 2009). Social networking sites are perhaps particularly interesting in their potential independence from organisational and administrative power structures. Communities on Facebook, for example, can be truly self-organising. However, increasingly, organisations including environmental NGOs are also using Facebook, Twitter and other new media to both generate participation and also as a form of supporter marketing; people who actively participate in campaigning for instance are more likely to become donors (Cubit, 2011). The effectiveness of organisational involvement in social networking to deliver change remains open to question, however; does it dilute the power of social networking as a mobilisation tool or strengthen it?

## 'Democratisation' of media

This 'democratisation' of media has consequences for the way in which individuals and communities respond, including the formation and dissolution of communities of interest around single issues and media content. Woodwatch is a set of campaigning tools for individuals and communities to protect trees and woodland important to them. A series of web pages provides guidance on setting up local groups, organising meetings and starting a local petition, as well as downloadable information on planning, campaigning and recognising important features in the woods (Woodland Trust, 2011b). A 'community' can come together around a single threat, and then disperse or move to a different phase once the threat has passed.

Whereas old media was controlled by relatively few people, new media creates a wider opportunity for participation and self-organisation. Individuals who use the internet for information exchange probably encounter more opportunities for recruitment into civic life and may be able to exert greater control over their environments, encouraging participation and enhancing trust (Shah *et al*., 2001). Use of the internet for information exchange is not without barriers. Ellul *et al*. (2008) found a mismatch between the web skills of active community group members and the web skills needed to access and process GIS held information provided by local authorities. This information is seen as essential in promoting active community participation in a range of spatial planning and consultation exercises on flood risk, air quality, planning applications and so on.

Although new media potentially makes participation easier and more accessible, is it less meaningful? How active is this kind of participation really? How much difference does it make to the individual and to social capital, compared with the physical act of planting a tree for instance?

## The role of NGOs and public bodies

While much of the premise of community participation is a shift in power from central authorities to communities, do NGOs and public bodies remain an important facilitator? A move from big government to Big Society can only be achieved if the opportunity for participation is matched by a 'tooling-up' of individuals, organisations and communities, equipping them with the knowledge, confidence and gateways to participation which match their circumstances and underlying limits on their capacities.

There are a number of reasons why continued involvement of public bodies and NGOs might be important. The first is to try to ensure representation of marginalised minority interests. A common criticism of participatory approaches is that they provide a platform to the most vocal and 'pushy' within a community, at the expense or even exclusion of other voices (O'Neill *et al*., 2006).

Secondly, it is a common feature of urban areas that the populations can be mobile and changing. The interests of future members of the community may not be represented by the interests of the current members. Pain (2005) reported that, particularly in deprived areas, young people are poorly represented in community activity, local policy making and consultation relating to open space.

Thirdly, NGOs and public bodies often have the skills and capacity to secure funding. Milton Keynes Parks Trust, created in 1992, is an example of a large community led trust which leases and manages much of the city's woods and parks. It was established as a charitable company with an endowment of property and other assets from the former Development Corporation. The Trust is managed by a Board of Trustees, drawn from the community and local organisations. Local people are able to participate and assume greater control over the way in the woods and parks are managed to meet local needs through involvement in governance of the community trust, volunteering in maintaining the asset, and getting involved in events. The Trust generates profits from its commercial assets, and reinvests them in its long-term financial security and providing extra services for the community (Parks Trust Milton Keynes, 2011).

Fourthly, the involvement of NGOs or public bodies in a community project can allow for the building of social capital. This may particularly be the case during the early stages, when communities need to acquire skills, develop trust, seek funding or build governance structures.

The Capital Woods Project in London managed by Trees for Cities has been able to support communities to re-engage with their local wood (O'Brien *et al*., 2009). By helping to tackle tipping, motor bike riders and anti-social behaviour, and through opportunities for people to volunteer to clear up the woods and join events, local people have been able to claim back green space 'turning these areas that have been perceived as no go into places that are turned round into the complete opposite.'

## Providing tools

In terms of new media, NGOs and public bodies can provide the tools which allow for participation or for the development of social capital. The Woodland Trust's MyView project is an example of the development of a web-based tool to support participation in local planning. Individuals or communities upload a digital image of their urban view to the website and can then manipulate it, inserting trees and other green cover to produce their ideal image of where they live or work or an area of importance to them. This can then be used to negotiate within the community or sent directly to local authorities responsible for developing spatial plans or management of the green space (Woodland Trust, 2010). The site also provides information on how to approach your councillor and which trees might be suitable to include in your MyView image.

The role of NGOs is not unproblematic. While they exist to serve public benefit, they are also established around representation of the interests of specific beneficiaries – disabled people, birds, the elderly, public access, etc. Representation of their beneficiaries may be in conflict with representation of a broad cross-section of the community.

## Research questions

Greater community participation in urban tree cover, whether demanded by communities, at the insistence of government, or as a result of the necessity of reduced central government funding, generates questions.

A greater emphasis on localism, whether in the guise of the Big Society or otherwise, is pushing both decision making and delivery of urban green space and urban tree cover to ever more local levels including a community level.

New media creates potential opportunities for wider or different forms of communication, but are these meaningful, do they lead to action and how should they be measured?

Is it becoming a substitute for more 'active' engagement or does it stimulate it? What does it say about governance? Can it ensure that a good quality urban environment which meets everyone's needs is provided?

We suggest ten questions for research:

1. What are the governance implications of a move to increasing localism and the Big Society approach to urban tree cover with different finance and tenure models?
2. What models of governance support a move to greater community participation in urban tree cover?
3. What do communities need to equip them to participate in a new, more local agenda?
4. If there is a shift to greater community participation in urban tree cover, how can the interests of all those living in the community be properly represented? How do we balance communities of interest with geographical communities?
5. What challenges does new media place on the governance and representation of interests in urban tree cover? Whose voice is legitimate, and how are those outside of new media use represented?
6. Do social network sites and other new media increase meaningful community participation and broaden representation in urban green space, including in policy and delivery?
7. Does engaging with new media translate to activity in the 'real world'? What makes people move from passive to active actors?
8. How should we measure the effectiveness of new media in facilitating participation in urban tree cover? What should be measured?
9. What is the role of the public sector and NGOs in facilitating and supporting individuals and communities and encouraging active participation? Is the structure and business model of NGOs suited to bottom-up community participation?
10. How can NGOs ensure a balance in the use of new media, including transmedia, as a fundraising tool while using it to deliver messages and catalyse action?

## References


38 DEGREES (2011). *Save our Forests*, 38 Degrees. [Online] Available at: http://www.38degrees.org.uk/page/s/save-our-forests [Accessed 04/03/11].

BALSALL HEATH FORUM (2011). About Balsall Heath Forum [Online] Available at: http://www.balsallheathforum.org.uk/start.htm [Accessed 4/03/11].

BARKER, M. AND BRIDGEMAN, C. (1994). *Preventing vandalism – what works?* Home Office Police Research Group. [Online] Available at: http://rds.homeoffice.gov.uk/rds/prgpdfs/fcdps56.pdf [Accessed 11/02/11].

BASINGSTOKE AND DEANE BOROUGH COUNCIL (2011). *Tree wardens*. [Online] Available at: http://www.basingstoke.gov.uk/leisure/conservation/treewardens.htm [Accessed 01/02/11].

BRISTOL STREET TREES (2009). *Our Street Trees are Under Threat.* [Online] Available at: http://www.bristolstreettrees.org/BRISTOLSTREETTREES/Home.html [Accessed 06/02/11].

BURTON, P., CROFT, J., HASTINGS, A,. GOODLAD, R., MACDONALD, G. AND SLATER, T. (2004). *What works in community involvement in areas based initiative? A systematic review of the literature.* Home Office online report 53/04. [Online] Available at: http://rds.homeoffice.gov.uk/rds/pdfs04/rdsolr5304.pdf [Accessed 11/02/11].

CAMERON, D. (2010). Big Society Speech, 19 July 2010, [Online] Available at: http://www.number10.gov.uk/news/speeches-and-transcripts/2010/07/big-society-speech-53572 [Accessed 22/01/11].

CHEETHAM, N. (2002). Community participation – what is it? *Transitions*. **14**(3), 2–6. [Online] Available at: http://www.advocatesforyouth.org/storage/advfy/documents/transitions1403.pdf [Accessed 01/02/11].

CLARK, G. (2010). *Participation in Planning*. Speech to Town and Country Planning Association, 30 November 2010, [Online] Available at: http://www.communities.gov.uk/speeches/corporate/participationplanning [Accessed 02/02/11].

CUBIT, E. (2011). Direct marketing focus: channel surfing. *Charity Times direct*. [Online] Available at: http://charitytimes.com/pages/ct_features/apr-may07/text_features/ct_apr-may07_focusfeature_channel_surfing.htm [Accessed 04/03/11].

DCLG (2008). *Communities in Control White Paper – real people, real power*. Department for Communities and Local Government TSO, London. [Online] Available at: http://www.communities.gov.uk/publications/communities/communitiesincontrol [Accessed 11/02/11].

DCLG (2009). *Empowering communities to influence local decision making. Evidence-based lessons for policy makers and practitioners.* HMSO, London. [Online] Available at: http://www.communities.gov.uk/documents/localgovernment/pdf/1241999 [Accessed 04/03/11].

DCLG (2010). *Localism Bill – an essential guide*. Department for Communities and Local Government. [Online] Available at: http://www.communities.gov.uk/publications/localgovernment/decentralisationguide [Accessed 11/02/11].

EAMES, M., MORTENSEN J.E., ADEBOWALE, M. AND LUDICISSA, L. (2009). *Towards a Community-led Agenda* *for Urban Sustainability Research: Insights from the Citizens Science for Sustainability (SuScit) Project*. Citizens Science for Sustainability, Uxbridge. [Online] Available at: http://www.suscit.org.uk/resources/documents/SuScitReport1FinalWebVersion090528_000.pdf [Accessed 11/02/11].

ELLISON, N.B., LAMPE, C. AND STEINFILED, C. (2009). Social network sites and society: current trends and future possibilities. *Interactions Magazine* **16**(1). [Online] Available at: https://www.msu.edu/~nellison/EllisonLampeSteinfield2009.pdf [Accessed 02/02/11].

ELLUL, C., HAKLAY, M. AND FRANCIS, L. (2008). *Empowering individuals and community groups – is Web GIS the way forward? In:* AGI GeoCommunity '08: Shaping a Changing World, Stratford upon Avon, UK. [Online] Available at: http://ucl.academia.edu/ClaireEllul/Papers/78773/Empowering_Individuals_and_Community_Groups_is_Web_GIS_the_Way_Forward [Accessed 11/02/11].

FORESTRY COMMISSION (2008). *An evaluation of Cydcoed: the social and economic benefits of using trees and woodlands for community development in Wales*. [Online] Available at: http://www.forestresearch.gov.uk/pdf/Cydcoed_final_report_Jan09.pdf/$FILE/Cydcoed_final_report_Jan09.pdf [Accessed 04/03/11].

FRIEDMAN, P. (2010). *Henry Jenkins video clip*. [Online] Available at: http://www.iijiij.com/2010/08/25/what-is-this-thing-called-transmedia-04830 [Accessed 04/03/11].

GUERRILLA GARDENING (2011). Guerrilla Gardening.org. [Online] Available at: http://www.guerrillagardening.org/gglinks.html [Accessed 01/02/11].

KONIJNENDIJK, C.C (2000). Adapting forestry to urban demands – role of communication in urban forestry in Europe. *Landscape and Urban Planning* **52**, 89–100.

KUO, F.E. (2003). The role of arboriculture in a healthy social ecology. *Journal of Arboriculture* **29**(3), 148–156.

KUO, F.E. AND SULLIVAN, W,C. (1996). Do trees strengthen urban communities, reduce domestic violence. *Arborist News* **5**(3), 33–34.

KUO, F.E. AND SULLIVAN, W,C. (2001). Aggression and violence in the inner city – effects of environment via mental fatigue. *Environment and Behaviour* **33**(4), 543–571, [Online] Available at: http://web.mac.com/wcsulliv/William_Sullivan/Publications_files/Kuo,%20Sullivan%202001%20aggresion.pdf [Accessed 27/01/11].

MILIBAND, D. (2006). Speech to the National Council for Voluntary Organisations annual conference Feb 2006. [Online] Available at: http://www.guardian.co.uk/society/2006/feb/21/localgovernment.politics1 [Accessed 22/01/11].

MOORE, S. (2003). *The use of public parks in England 2003*. Sport England, London.

MORRIS, J. (2006). *Removing the barriers to community participation*. National Community Forum. [Online] Available at: http://www.communities.gov.uk/publications/communities/removingbarriers [Accessed 01/02/11].

NORMAN, J. (2010). *The Big Society – the anatomy of the new politics*. University of Buckingham Press, Buckingham.

O'BRIEN, L., OWEN, R., SINGH, J. AND LAWRENCE, A. (2009). *Social dynamics of London's trees, woodlands and green spaces.* Forestry Commission England, London. [Online] Available at: http://www.forestry.gov.uk/fr/INFD-62FASU, [Accessed 11/02/11].

O'NEILL, J., CARTER, C., EKELI, K. AND KENYON, W. (2006). *Representing Diversity in Participatory Approaches.* PATH Policy Brief. [Online] Available at: http://www.macaulay.ac.uk/economics/research/path/PATH%20Policy%20Brief.pdf [Accessed 04/03/11].

PAIN, R. (2005). *Intergenerational relations and practice in the development of sustainable communities.* Background paper for the ODPM, International Centre for Regional Regeneration and Development Studies (ICRRDS), Durham University. [Online] Available at: http://www.dur.ac.uk/resources/cscr/odpm/Intergeneration.pdf [Accessed 04/03/10].

PARKS TRUST MILTON KEYNES (2011). *The Trust and the Parks Trust model*. [Online] Available at: http://www.theparkstrust.com/parks-trust/DisplayArticle.asp?ID=33178 [Accessed 12/02/11].

PERKINS, D.D. AND ZIMMERMAN, M.A. (1995). Empowerment theory, research and application, *American Journal of Community Psychology, 1* October 1995. [Online] Available at: http://business.highbeam.com/435401/article-1G1-18498725/empowerment-theory-research-and-application [Accessed 05/03/11].

PRATCHETT, L., THORP, L., WINGFIELD, M., LOWNDES, V. AND JABBAR, R. (2010). *Preventing Support for Violent Extremism through Community Interventions: A Review of the Evidence.* Rapid Evidence Assessment Summary Report. Department for Communities and Local Government, London. [Online] Available at: http://www.communities.gov.uk/documents/communities/pdf/1518004.pdf [Accessed 11/02/11].

RED ROSE FOREST (2010). *Green Streets.* [Online] Available at: http://www.redroseforest.co.uk/web/content/view/43/143/ [Accessed 01/02/11].

RIFKIN, S.B. AND KANGERE, M. (2002). *What is Participation? In: CBR a participatory strategy in Africa*. (ed.) Hartley, S., Chapter 3, pp 37–49, University College of London. [Online] Available at: http://www.asksource.info/cbr-book/cbr03.pdf [Accessed 01/02/11].

RISHBETH, C. (2004). Re-placed people, re-visioned landscapes: Asian women migrants and their experience of open space. *In: Open Space People Space: an International Conference on inclusive Environments*, Edinburgh. [Online] Available at: http://www.openspace.eca.ac.uk/conference/proceedings/PDF/Rishbeth.pdf [Accessed 11/02/11].

SADAN, E. (2004). *Empowerment and community planning*. [Online] Available at: http://www.mpow.org/elisheva_sadan_empowerment.pdf [Accessed 06/02/11].

SHAH, D.V., KWAK, N. AND HOLBERT, R.L. (2001). Connecting and disconnecting with civic life: patterns of internet use and the production of social capital. *Political Communication* **18**, 141–162.

SMITH, M.K. (2001). 'Community', T*he encyclopaedia of informal education*. [Online] Available at: http://www.infed.org/community/community.htm [Accessed 11/02/11].

SRIVASTAVA, L. (2009). *Transmedia Activism: Telling Your Story Across Media Platforms to Create Effective Social Change*. Media Rights. [Online] Available at: http://www.mediarights.org/news/Transmedia_Activism_Telling_Your_Story_Across_Media_Platforms_to_Create_Eff/ [Accessed 04/03/11].

TOWNSEND, M. (2006). Feel blue? Touch green! Participation in forest/woodland management as a treatment for depression. *Urban Forestry and Urban Greening* **5**, 111–120.

TRANSITION TOWN TOTNES (2011). *Nut tree planting project*. available at: http://www.transitiontowntotnes.org/projects/nut-tree-planting-project [Accessed 01/02/11].

UNESCAP (2009). *Regional trends, issues and practices in rural poverty reduction – Case Studies on Community Participation*. [Online] Available at: http://www.unescap.org/pdd/publications/poverty_and_development/trends_rural.pdf [Accessed 1/2/11].

VAN HERZELE, A., COLLINS, K. AND TYRVAINEN, L. (2005). Involving People in Urban Forestry – a Discussion of Participatory Practices throughout Europe. *In: Urban Forests and Trees*, Konijnendijk, C.C., Nilsson, K., Randrup, T.B. and Schipperijn, J. (eds.) Springer, New York, Chapter 8, pp. 207–288.

WESTPHAL, L.M. (1999). *Growing Power. Social benefits from urban greening projects*. University of Illinois at Chicago. [Online] Available at: http://www.ncrs.fs.fed.us/pubs/jrnl/1999/nc_1999_Westphal_001.pdf [Accessed 06/02/11].

WESTPHAL, L.M. (2003). Urban greening and social benefits: a study of empowerment outcomes. *Journal of Arboriculture* **29**(3), 137–147.

WOODLAND TRUST (2002). *Urban Woodland Management Guide 1 – Damage and misuse*. Woodland Trust, Grantham. [Online] Available at: http://www.woodlandtrust.org.uk/SiteCollectionDocuments/pdf/urbanwoodlandguide1.pdf [Accessed 12/02/11].

WOODLAND TRUST (2010). *MyView and your Councillor.* [Online] Available at: http://www.woodlandtrust.org.uk/en/campaigning/my-view/Pages/local-authorities.aspx

WOODLAND TRUST (2011A). *Pepper Wood community resource*. [Online] Available at: http://www.pepperwood.co.uk/ [Accessed 04/03/11].

WOODLAND TRUST (2011B). *Woodwatch.* [Online] Available at: http://www.woodlandtrust.org.uk/en/campaigning/woodwatch/Pages/default.aspx [Accessed 06/02/11].

# Investigation into the interactions between closed circuit television and urban forest vegetation in Wales


## Abstract

In the past 20 years the UK has seen extraordinary growth in the use of CCTV (closed circuit television) to tackle crime and anti-social behaviour. The proliferation of open space CCTV cameras in the UK has led to concern that they are detrimentally affecting urban forest vegetation because of the desire to cut or fell vegetation to maximise the coverage provided by cameras and conversely that vegetation is reducing the effectiveness of CCTV. The guidance relating to the use of open space CCTV does not give meaningful advice regarding the deployment of CCTV in areas of existing urban forest vegetation. Results of this research found that the obstruction of cameras by vegetation was considered to be a major threat to CCTV and that CCTV was an issue of concern to urban forest managers. Despite the concerns expressed by stakeholders there has been minimal co-operation between CCTV managers and tree managers even though greater co-operation would be welcomed.

Results of this research have found that trees are the type of vegetation that most affects CCTV camera sightlines. The majority of vegetation affecting CCTV is situated in town squares, pedestrianised streets or other highway land. Where urban forest vegetation obstructs CCTV cameras the solution was to cut back or occasionally fell the obstruction. Installing more cameras or the relocation of obscured cameras was not undertaken as a solution. Despite concerns, the amount of cutting back and felling to address conflicts is relatively low. This elevated level of concern may be attributed to the significant amenity afforded by the affected trees and efforts to maximise the effectiveness of CCTV for public safety reasons.


## Introduction

### Closed circuit television growth

The growth of open space CCTV (closed circuit television) for use in public and quasi-public areas has been phenomenal with the UK recognised as a leading user of CCTV for community safety and crime investigation purposes (Fry, 2008). In its most basic form CCTV is simply a camera and monitor directly connected by a closed loop, most commonly with wires but also in some cases microwave or infrared beams. CCTV surveillance systems will include many cameras sending images back to a monitoring room, referred to as a CCTV suite, which can cover several towns or districts of a city.

Despite the rapid growth of CCTV there are no official figures for the total number of CCTV cameras in the UK. Based on research carried out by McCahill and Norris, (2002) the popular press have claimed that there are over 4 million CCTV cameras in the UK; however, this figure is not considered reliable because it is based on an extrapolated survey confined to two London streets. A more reliable figure for the number of CCTV cameras in the UK is provided by Fry (2008) who estimates that there are 1.5 million cameras surveying public and quasi-public areas including shopping malls, hospitals and universities.

Between 1994 and 1999 the Home Office awarded £38.5 million towards the cost of 585 CCTV schemes (Armitage, 2002) and under the Home Office's Crime Reduction Strategy (1999–2003) the amount of funding increased to £170 million which was sufficient to support the introduction of a further 680 CCTV schemes (Larsen, 2009). By 1995 CCTV funding


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equated to 78% of the Home Office budget for crime prevention (Goodwin *et al.*, 2000). In 2004 it was claimed that London had become the unrivalled CCTV capital of the world with 22 of the 32 boroughs having their own street systems utilising over 1000 cameras (Hemper and Topfer, 2004).

## CCTV, urban forest vegetation and crime

Notwithstanding the rapid growth and investment in open space CCTV, a study undertaken for the Home Office by Farrington and Welsh (2002) found that CCTV had no effect on violent crime (in five of the CCTV schemes studied) and only reduced overall crime by 4%. In another Home Office report (Gill *et al*., 2005) studying the impact of CCTV on crime only two of the 14 case studies experienced a statistical difference in the level of crime due to CCTV. The report also acknowledged that it was unrealistic in the extreme to expect CCTV to counter complex social problems. Despite the research, most people's perception of open space CCTV is that it is very effective at detecting crime and effective at preventing crime (Charman and Honess, 1992). CCTV is now considered part of everyday life, with most members of the public willing to sacrifice personal privacy for safety and security (Webster, 2009).

Claims in the literature that CCTV is not a panacea for crime coincided with reports (CABE, 2004; ODPM, 2004) that the prevention of anti-social behaviour and crime in public spaces is better addressed by good urban design, promoting natural surveillance and better management. Research has found that criminals will use vegetation to aid concealment (Michael *et al.*, 2001) and that there is a greater fear of crime on sites which provide cover, escape or refuge for offenders (Talbot and Kaplan, 1984; Fisher and Nasar, 1992). It is not the case that all vegetation will block views, as research by Kuo and Sullivan (2001) found that high canopy trees did not encourage crime. Even where vegetation reduces natural surveillance, residents in poor districts have a higher sense of safety in areas of high density tree planting (Kuo, 1998). The reasons for this are that tree planting contributes to a sense of ownership and that this leads residents to care for the area. The benefits that trees provide to people's mental health and wellbeing have been widely researched. Patients that have a view of a natural setting recover more rapidly (Ulrich, 1984) and natural features reduce stress and aggression (Kuo and Sullivan, 2001).

## CCTV and urban forest interactions

Government-funded research (Britt and Johnston, 2008) has identified CCTV as an issue of concern amongst local authority tree officers with survey responses citing a lack of awareness of the problem and indicating poor public support for the retention of trees where they obstruct camera sightlines. In addition, the popular press has highlighted the issue (*Lancashire Evening Post*, 2007; *Daily Mail*, 2008; *Luton Today*, 2008; Magill, 2008) with articles expressing public opinion both for and against the retention of urban forest vegetation where it affected open space CCTV. Significantly, some residents saw CCTV as the best means of improving their neighbourhood and demanded the removal of trees where they restricted visibility. There is an absence of research examining how the spread of open space CCTV has affected urban forest vegetation; nevertheless, it is the author's experience that CCTV camera sightlines and urban forest vegetation frequently conflict with each other.

## CCTV regulation and guidance

Specific powers to introduce public open space CCTV were granted to local authorities by the Government under Section 163 of the Criminal Justice and Public Order Act 1994 (HMSO, 1994). This Act is supplemented by the now updated version of the CCTV Code of Practice 2008 (ICO, 2008), which clarifies the general provisions for CCTV. The Code of Practice is mainly concerned with data protection, as it is this aspect of CCTV that is a legal requirement. As a result only a single page of the Code of Practice is devoted to the selection and siting of cameras. Within this page the only reference made to vegetation is by way of an example which states, 'Check that a fixed camera positioned in winter will not be obscured by the growth of spring and summer foliage'.

The current Code of Practice and the Crime and Disorder Act 1998 forms part of the Government's wider strategy (HMSO, 1998, 2002 and 2006) on crime prevention and community safety, which places a statutory duty on the police, local authorities and other agencies to work together to improve community safety. These partnerships heavily promoted the use of open space CCTV in their early strategic assessments.

Under the provisions of the Town and Country Planning Act 1990 (HMSO, 1990a) and related Acts (HMSO, 1995, 1990b) CCTV cameras mounted on poles over 4 m in height require planning permission. CCTV cameras fixed to the outside of buildings do not normally require planning permission unless the building is listed. In considering applications for pole-mounted CCTV cameras local planning authorities should consider visual impact.

## Urban forest vegetation

Urban forest vegetation comprises trees, shrubs, hedges and woody vines (Miller, 1997). Whilst open space CCTV has been a recent introduction trees have been an integral part of city landscapes for centuries (Bradshaw *et al.*, 1995). Urban forest vegetation is an important asset which provides numerous and varied benefits (CABE, 2005; NUFU, 2005; Trees and Design Action Group, 2010) that are now becoming more widely appreciated.

# Materials and methods

The empirical research investigated the extent of open space CCTV provision in Wales, examined the interactions between CCTV and urban forest vegetation, and where conflicts occurred investigated how they were resolved. The research targeted local authority tree managers and CCTV managers because they are the respective professionals most directly involved with the issues under investigation.

In January 2010 all local authority CCTV managers in Wales were emailed and invited to participate in the research by following a link to a web-based questionnaire. The following month local authority tree managers were sent a link to a comparable questionnaire inviting participation in the research. As the management of trees within local authorities is often fragmented it was necessary to collect data from land managers who have responsibility for trees, as well as specialist tree officers. Both questionnaires were structured to enable comparison between the two strands of research. Reminder emails were sent out five days before each of the deadlines expired. This was followed by an extension of the initial deadline and personalised emails to non-respondents. Following the extended deadline non-respondents were contacted by telephone, which resulted in several additional responses. To augment the questionnaire research two open space CCTV case studies were also undertaken which involved an in-depth interview with managers of the system.

# Results

Just over 45% of local authorities provided at least one response to the tree manager questionnaire. The majority of responses (83%) were provided by specialist tree officers with the remainder provided by generic managers of local authority land. Slightly less than 70% of Welsh local authorities provided a response to the CCTV manager questionnaire indicating a high level of interest in the research. The most popular years for open space CCTV introduction were 1996 and 2001 with the sums invested ranging from less than £100 000 in one authority to over £800 000 in four authorities. The number of open space CCTV cameras in each local authority also varied considerably from 23 to 360 (mean = 108) and showed a positive correlation to each authority's population.

## Urban forest and open space CCTV threats

CCTV managers identified the provision of budgets (long and short term) as the greatest threat to CCTV. This was followed by the obstruction of CCTV cameras by vegetation, with 46% of CCTV managers ranking it as the greatest or second greatest threat. This placed vegetation obstruction above other perceived threats to CCTV including rights to privacy, freedom of information, greater regulation and negative press coverage.

When asked to rate various obstructions to CCTV camera sightlines, trees were the most frequent obstruction followed by signs and other street furniture. All of the responses indicated that obstruction by trees was at least sometimes a problem. Shrubs were identified as being an occasional obstruction whilst hedges were considered to be a frequent obstruction in only two responses. Climbing plants were not identified as a cause for concern.

By contrast tree managers ranked the threat posed by CCTV as the seventh greatest risk to urban trees (Table 1), indicating that it is considered to be a moderately low issue of concern.

**Table 1** Ranked threats to urban trees according to tree managers.

| Threat to urban trees | Nominal values | Rank |
|---|---|---|
| Development | 81 | 1 |
| Limited budgets | 70 | 2 |
| Highways requirements | 67 | 3 |
| Over-zealous risk management | 59 | 4 |
| Disease | 55 | 5.5 |
| Underground and overhead utilities | 55 | 5.5 |
| Open space CCTV | 44 | 7 |
| Climate change | 41 | 8.5 |
| Satellite television | 41 | 8.5 |
| Other, please rate and specify below | 35 | 10 |
| Tree-related subsidence | 30 | 11 |

## CCTV and urban forest vegetation interactions

The research also showed that many requests to cut back trees over 10 m were repeat requests, where trees had been previously cut back within the past three years. The majority of trees obstructing CCTV were situated 5–15 m from the affected camera and occasionally were less than 5 m away. One CCTV manager referred to a tree in excess of 50 m from the camera as causing an obstruction.

Trees were most likely to obstruct open space CCTV cameras when situated in town or city squares. This was closely followed by pedestrianised streets or precincts and highway verges. Trees in council-maintained parks and gardens, education campuses and council car parks were also likely to obstruct CCTV; however, the frequency of obstruction in these three areas was much less than the first three categories. Privately owned vegetation was not considered to be an issue or was possibly not addressed by CCTV managers.

The majority of vegetation affecting CCTV was deciduous (87%) with maple (*Acer* spp.), oak (*Quercus* spp.) and plane (*Platanus* spp.) most frequently obstructing CCTV cameras. This was followed by lime (*Tilia* spp.), Italian alder (*Alnus cordata*), whitebeam (*Sorbus* spp.), poplar (*Populus* spp.) and ash (*Fraxinus* spp.).

To address CCTV obstruction, 70% of tree managers frequently used 'crown lifting' (i.e. the removal of lower branches) or reduction in branch spread. All tree managers stated that they had not undertaken the topping of trees to address CCTV obstruction which is incompatible with sympathetic arboricultural management. Window or notch cutting was not a favoured method of reducing CCTV obstruction. Six local authorities gave estimates for the cost of carrying out additional tree works (felling and pruning) in the past five years to address CCTV obstruction. The estimated costs ranged from £450 to £30 000 with funding to carry out additional work provided by CCTV and general land management budgets in addition to tree budgets.

An example of inappropriate tree work is shown in Figure 1. The photograph is an actual CCTV camera screenshot of a mature Italian alder (*Alnus cordata*) that is growing on a busy street. The tree has been 'topped' providing an unnatural shape and affecting its long-term viability. The work was sanctioned by the highways department at the request of the CCTV manager who considered it necessary to maintain a view along the road seen in the background. The work will need to be repeated every few years if visibility is to be maintained.

The short term (0–3 years) effects of cutting back to improve visibility were considered to be 'negative' by 70% of tree managers and 'very negative' by 10%. The long-term (more than 3 years) effect of cutting back trees was considered to be 'negative' in 90% of cases. Where trees were removed

**Figure 1** Winter CCTV screenshot of *Alnus cordata* 'topped' to increase CCTV visibility.

66% of tree managers stated that replacement planting 'nearly always' did not take place.

When CCTV managers were asked about possible solutions to CCTV obstruction by vegetation (Table 2) 80% considered that the most appropriate solution was to either carry out heavy pruning on a three-year cycle or lighter pruning every year. None of the CCTV manager responses considered that felling trees without replanting was the most appropriate solution and none considered additional CCTV cameras to be the most appropriate solution. The second and third most appropriate choices made by CCTV managers increasingly favoured felling on its own, felling with replacement planting and additional CCTV cameras.

In contrast tree managers favoured more CCTV or the relocation of cameras to a different position as the most appropriate and second most appropriate solutions when asked the same question. Other possible solutions put forward by tree managers were fewer CCTV cameras, more natural surveillance, better consultation and design.

CCTV managers were of the opinion that the amount of urban forest vegetation obstruction had increased in the past five years. Twenty per cent considered that the amount of obstruction had 'significantly increased' in the past five years whilst 60% stated that it had 'increased'. These responses can be compared with those made by tree managers where 45% stated that the number of requests to cut back or fell trees had remained the same, 33% stated that the requests had increased and 22% stated they had decreased over the same period.

Table 2 Solutions to camera obstruction chosen by CCTV managers and tree managers.

| | Most appropriate | | Second most appropriate | | Third most appropriate | |
|---|---|---|---|---|---|---|
| | CCTV | Tree | CCTV | Tree | CCTV | Tree |
| Felling trees | 0% | 8% | 7% | 0 | 20% | 12% |
| Felling trees and replacement with 'CCTV friendly' trees and shrubs | 7% | 0% | 20% | 0 | 33% | 0% |
| Heavy tree pruning to ensure that no obstruction occurs for at least three years | 40% | 8% | 33% | 11% | 0% | 0% |
| A commitment to less drastic but more frequent annual tree pruning | 40% | 0% | 20% | 11% | 13% | 64% |
| The relocation of CCTV cameras to a different position | 13% | 25% | 13% | 56% | 0% | 0% |
| Additional CCTV cameras to provide coverage from different angles | 0 | 33% | 7% | 22% | 20% | 12% |
| Other | 0 | 25% | 0 | 0 | 14% | 12% |

## Perspectives

CCTV managers consider that there is strong public support for CCTV and urban trees with a significant majority (87%) agreeing that the public is very supportive of open space CCTV. However, the majority of CCTV managers (73%) also agree that that the public is very supportive of urban trees and the benefits they provide. Tree managers have a similar awareness of the public's attitude towards urban trees with the majority (84%) agreeing that the public is very supportive of urban trees. However, tree managers are of the opinion that the public is much less supportive of open space CCTV (44%) when compared to urban trees.

Thirteen per cent of CCTV managers considered that, 'CCTV is the best means of combating crime and anti-social behaviour in town centres…', while nearly three-quarters (73%) agreed with the statement to some extent. One-fifth of CCTV managers disagreed with the statement, perhaps indicating an awareness of CCTV's limitations. Unsurprisingly, CCTV managers considered the police to be strong supporters of CCTV and considered that senior management, local councillors and residents/proprietors also tended to favour CCTV where it was obstructed by vegetation. The local press however were considered to have a slight bias towards favouring trees.

In their responses to the same question tree managers agreed that the there was a strong bias for the police to favour CCTV but also felt that local councillors and residents/proprietors strongly favoured CCTV. Tree managers did not consider that the press had any bias. Additional comments were provided by tree managers in response to this question. One stated that in many cases reasonable compromises were made and another felt that he usually won the argument with mature high amenity trees.

The research found a high level of dissatisfaction with the design of open space CCTV. The majority (61%) of CCTV managers and nearly all tree managers (90%) who expressed an opinion disagreed with a statement to the effect that the CCTV system in their area adequately considered existing trees when it was designed.

CCTV and tree managers were asked about how they thought the number of urban trees and CCTV cameras might change in the next 15 years. CCTV managers predicted that the number of both will increase, with 64% stating that the number of trees will increase and 78% stating that the number of CCTV cameras will increase. In comparison tree managers were more sceptical about the number of trees with only 39% predicting their number will increase and 31% predicting a decrease. Over three-quarters (77%) of tree managers predicted that the number of CCTV cameras will increase.

## Consultation and guidance

The responses from both questionnaires show that there is very little or no consultation between those who represent the interests of CCTV and those who represent the urban forest. Where CCTV had been installed by engineers in areas of existing tree cover three-quarters of tree managers stated that they had not been consulted. The same amount (75%) of CCTV managers had not been consulted over proposed schemes of tree planting in areas of open space CCTV. Even though there was very little consultation both CCTV managers and tree managers felt strongly that there was a need for them to be consulted over proposals that might affect them. Concern over the potential for existing CCTV cameras to be obstructed meant that a small minority of CCTV managers did not want to see any new tree planting.

Fifty per cent of tree managers used recognised national guidelines on community safety (e.g. Secured by Design, Crime Prevention through Environmental Design) in the design of tree planting schemes. All tree managers were supportive of the idea of introducing spatial design guidance that specifically covered tree planting and methods to deter crime, such as natural surveillance and CCTV. Two-thirds of CCTV managers (67%) were also supportive of the idea.

## Case study 1 Flintshire County Council (FCC)

Open space CCTV surveillance was introduced in Flintshire at the end of 2002 with 11 cameras. The initial installation cost £180 000 with approximately half the funding from the Home Office and the remainder from FCC (£35 000), North Wales Police (£35 000) and the private sector (£25 000). Since 2002 the system has been extended to 94 cameras providing continuous coverage in town centres, industrial estates, residential areas and country parks. In addition a further 23 cameras have been installed in schools and are monitored by the CCTV suite under a service level agreement. The design and installation of the system was project managed by the Highways Department who undertook consultations with town councils and submitted 74 planning applications to the local planning authority between 1998 and 2004 to erect pole-mounted cameras.

The CCTV manager considered that the main factor affecting the operation of CCTV was the Council's policy of gradually phasing in new low energy street lighting which adversely affected the quality of night-time images. Secondary to this is the effects of trees, flags, banners and bunting (strings of small flags hung between buildings) obscuring cameras. It was considered that the obstruction of CCTV cameras by trees is a critical factor that limits its effectiveness and that the system's original design and subsequent extensions had failed to take into account vegetation. Reference was also made to tree planting carried out on landscaped mounds that screen factories on an industrial estate. The planting had been carried out after CCTV had been installed in the area. With time the trees had grown to a height where they obstructed pole-mounted cameras.

The CCTV manager considered that obstruction is most acute during the summer when deciduous trees are in leaf. During the winter obstruction by bare branches was tolerated because cameras could see through the crowns. The position of one particularly high street camera was criticised by the CCTV manager. This camera had been planned and installed during the winter and was said to be rendered useless the following spring when a nearby tree came into leaf.

In response to the mainly seasonal nature of the obstruction the CCTV manager had resorted to writing to the departments and organisations responsible for trees obscuring CCTV cameras on an annual basis. During the summer of 2009 the CCTV manager sent a standard letter to tree managers who were responsible for trees affecting 23 CCTV cameras at various locations. All but one of the locations was managed by the local authority but because they were the responsibility of different departments the vegetation obstruction was difficult to resolve. The CCTV manager considered that the fragmented nature of local authority tree management resulted in inconsistent outcomes with only a quarter of requests for vegetation to be cut being resolved satisfactorily. To achieve more satisfactory outcomes the CCTV manager was willing to fund the cost of pruning works out of the CCTV budget.

Despite the CCTV manager's experience the preferred solution for dealing with vegetation obstruction was to commit to less drastic and more regular pruning rather than insist on its complete removal. Relocating cameras or installing additional cameras to overcome vegetation obstruction were not considered viable due to cost. The CCTV manager stated that open space CCTV was an important tool in combating crime and anti-social behaviour and was confident in its capabilities. It was acknowledged that vegetation was a feature of the urban environment and that CCTV and trees could coexist.

## Case study 2 Wrexham town centre

The first installation of open space CCTV in the town centre took place in 1996 with the deployment of 13 cameras. Camera positions were determined by senior police and council officers who assessed sites using a mobile platform. The initial installation was soon supplemented with a further 12 cameras that has now evolved to include 126 cameras in the town centre and elsewhere in the county.

The Security Client Manager considered that CCTV funding was a major cause for concern and was aware that criminal behaviour was being modified to avoid detection. The Security Client Manager stated that vegetation obstruction was not considered to be a critical issue but was a greater threat to CCTV than more regulation and public concern over privacy. The problem of vegetation obstruction was again identified as being mainly confined to the summer months when deciduous trees are in leaf. During the winter cameras were said to be able to see through the bare branches of trees; however, it was stated that the autofocus mechanism on cameras would sometimes focus on a near branch rather than a distant object under surveillance. It was also claimed that the milder winters and wetter summers were leading to more luxuriant growth which remained on trees for longer periods of time.

The Security Client Manager estimated that five requests had been made to the tree officer in the past three years and that the majority of these had not resulted in any major work. All requests affected *Sorbus* spp. and it was admitted that vegetation obstructing cameras would occasionally be removed without consulting the relevant tree manager. It was claimed that high street trees planted in the 1980s were now becoming a problem and for this reason the frequency of obstruction by trees would increase.

Reference was made to an incident where a woman police officer had been assaulted and the crime had not been caught on camera because the incident had been obstructed by a tree. The incident led to a request for the tree to be felled. However, this was strongly opposed by the local councillor who is known to be a strong supporter of the environment. This was sufficient to ensure the tree's retention.

The Security Client Manager judged the town centre CCTV surveillance system to be a success and cited a local press article which claimed that it was one of the most successful schemes in Wales (Robinson, 2009). As the Security Client Manager had previously had a career advising about crime reduction he was aware of the role of good design and acknowledged that it was more important than CCTV.

## Discussion

Results of this research have found that 1993 was the earliest year for the introduction of open space CCTV by a local authority, thus illustrating how recently a concept which is now part of everyday life was introduced. In the 1990s CCTV was heavily promoted by the Government as *the* crime prevention method of choice and the public have largely agreed with its deployment. Despite being heavily promoted and accepted, the introduction of open space CCTV has not been accompanied by any meaningful guidance on how it should be sympathetically incorporated within the existing urban environment. It is also evident that the planning system has not acted as a safeguard either. The reasons for this are considered to be the lack of planning guidance for this aspect of CCTV, the public support for CCTV and the fact that certain types of installation can be undertaken without planning permission.

In the majority of cases, open space CCTV will have been installed after any urban forest vegetation had been planted and allowance should have been factored into its design to ensure obstruction did not occur. In these cases it is considered that CCTV has been brought into conflict with urban forest vegetation. However, CCTV has not always been installed after urban forest vegetation has been planted and one case study referred to existing CCTV cameras being obscured by new tree planting. As the period of time that CCTV has been present increases this type of conflict is likely to become more common. A small minority of CCTV managers were so concerned about this eventuality that they wanted a moratorium on new tree planting in areas of existing open space CCTV. Tree managers also believe CCTV has reduced the opportunities for new planting. These findings will inevitably present additional challenges to landscape architects and tree officers wanting to plant in a crowded urban environment.

After its rapid introduction open space CCTV is now becoming a maturing technology that will continue to have a place in the urban environment. The withdrawal of generous grants and a more holistic approach to crime prevention mean that the growth of CCTV has slowed in recent years. This does not mean that the interactions between CCTV and urban forest vegetation will decrease for three reasons. Firstly, the CCTV industry still wishes to promote the further expansion of CCTV in public and quasi-public areas such as schools. Secondly, projects of regeneration will provide opportunities for new schemes of planting and also additional CCTV surveillance. Lastly, as trees are dynamic the incidence of obstruction will change even if the number of trees and CCTV cameras remains static.

Unfortunately, due to the fragmented nature of local authority tree management and limited responses to this aspect of the research, the degree to which CCTV affects urban forest vegetation in numerical terms is uncertain. Within the limited sampling that the tree manager survey provided, indications are that in the three years leading up to the survey there were 400 instances in Wales of tree felling or cutting back due to CCTV. Using data from six local authorities the cost of additional tree work in the past five years is estimated to be £10 000 for each Welsh local authority. The majority of remedial work was confined to cutting back trees or occasional tree removal, and this method was favoured much more where trees less than 10 m caused an obstruction. Shrubs and hedges were affected much less indicating that CCTV is a problem affecting urban trees rather than urban forest vegetation generally. The trees affecting CCTV are nearly all deciduous and fairly evenly divided between small tree less than 10 m and larger trees greater than 10 m.

The relocation of existing cameras or new cameras was not considered an option for financial reasons with the cost of buying and installing an additional camera estimated to be £12 000 to £15 000 and the cost of relocating a camera being several thousand pounds. Tree managers are now increasingly using valuation methods (Nielan, 2010) to place a financial value on the amenity provided by trees and are able to calculate the loss in amenity that would result from cutting back and felling trees to accommodate CCTV. This approach is particularly relevant for open space CCTV as the trees which come into conflict with it are most likely to be prominently situated with high amenity value and where crown symmetry and other aesthetic aspects are important. The adoption of this approach and its acceptance by non-tree professionals will promote the retention of urban forest vegetation and encourage technological solutions.

The importance of good CCTV design is reflected in the two case studies. The CCTV system in Wrexham town centre had a considered approach with potential camera positions being checked in advance of installation using a lifting platform. This approach has resulted in fewer conflicts with trees to the extent that the CCTV manager considered that it is not a significant problem. By contrast, the open space CCTV system in Flintshire appears to have been designed without consideration of existing trees. This soon resulted in cameras being obstructed and requests for vegetation to be cut back for overriding public safety reasons. In the worst case a camera installed during the winter was rendered 'useless' the following summer by leaves on a nearby deciduous tree causing a severe obstruction to the camera's view. This is the result of very poor design. The failure of early CCTV systems to adequately consider tree growth may have been a genuine oversight due to the lack of meaningful guidance; however, it is also possible that CCTV designers assumed that vegetation would be managed to not impede cameras in the belief that CCTV should always take precedence.

Whilst the empirical research focused on the interaction between CCTV and urban forest vegetation, failure to consider why these respective elements are components of urban areas would have been a major omission. Urban forest vegetation and open space CCTV are considered to have a value to society which exceeds their net cost. CCTV is used as a method of promoting safer communities whilst urban forest vegetation is a fundamental part of greener and more attractive urban environments. Both of these elements are key Government policies (ODPM, 2002) that promote sustainable and safer communities and aim to improve the quality of life for urban dwellers. At first the objectives of open space CCTV and those for planting urban forest vegetation appear to be mutually exclusive. However, the research demonstrates that vegetation and the creation of quality urban space can reduce crime and anti-social behaviour. This aspect of urban forest vegetation needs to be given greater emphasis by architects and town planners if a more integrated approach to good urban design is going to be achieved.

It is an inevitable conclusion that the benefits afforded by urban forest vegetation and open space CCTV are best achieved in conjunction with each other as part of good urban design, rather than allowing them to compete. Notwithstanding, it is apparent that there is very limited consultation between tree managers and CCTV managers and they often act independently. This is disappointing because the research also found that both stakeholders consider consultation essential and that, in the majority of cases, the views of tree officers and CCTV managers are not particularly polarised.

At the time of writing the London Tree Officer Association is preparing guidance for stakeholders regarding the interactions between open space CCTV and urban trees. It is expected that the guidance will address many of the stakeholders' concerns relating to poor planning and consultation that are discussed above as well as containing a protocol for the resolution of CCTV and vegetation conflicts.

## References


ARMITAGE, R. (2002). *CCTV or not to CCTV?* NACRO.

BRADSHAW, A., HUNT, B. AND WALMSLEY, T. (1995). *Trees in the Urban Landscape, Principles and Practice*. Spon Press, Taylor and Francis Group, London and New York.

BRITT, C. AND JOHNSTON, M. (2008). *Trees in Towns II*. Department of Communities and Local Government, London.

CABE (2004). *Policy Note: preventing anti-social behaviour in public spaces*. CABE Space, London.

CABE (2005). *Does Money Grow on Trees?* CABE.

CHARMAN, E. AND HONESS, T. (1992). *Closed circuit television in public places: its' acceptability and perceived effectiveness*. Police Research Group. Crime Prevention Unit Series: Paper No.35. Home Office Police Department, London.

DAILY MAIL (2008). Resident who chopped down trees used by yobs to hide from CCTV camera is arrested and charged with criminal damage. *Daily Mail* 8 October

2008. [Online] Available at:http://www.dailymail.co.uk/news/article-1073530/Resident-chopped-trees-used-yobs-hide-CCTV-camera-arrested-charged-criminal-damage.html [Accessed 18/04/09].

FARRINGTON, D.P. AND WELSH, B.C. (2002). *Crime Prevention Effects of CCTV: a Systematic Review*. Home office research study 252.

FISHER, B.S. AND NASAR, J.L. (1992). Fear of crime in relation to three exterior site features. *Environment and Behavior* **24**(1), 35–65.

FRY, P. (2008). *How Many Cameras Are There?* CCTV User Group. 18 June 2008. [Online] Available at: http://www.cctvusergroup.com/art.php?art=94 [Accessed 29/11/09].

GILL, M., SPRIGGS, A., ALLEN, J., ARGOMANIZ, J., BRYAN, J., JESSIMAN, P., KARA, D., KILWORTH, J., LITTLE, R., SWAIN, D. AND WAPLES, S. (2005). *The Impact of CCTV: Fourteen Case Studies*. Home Office.

GOODWIN, M., JOHNSTONE, C. AND WILLIAMS, K.S. (2000). CCTV Surveillance in Britain: Beyond the Rhetoric of Crime Prevention. *In:* Gold, R.G. and Revill, G. (eds.) *Landscapes of Defence*. Pearson Education Ltd., Singapore.

HEMPER, L. AND TOPFER, E. (2004). *CCTV in Europe – Final Report*. Urban Eye. [Online] Available at: http://www.urbaneye.net/results/ue_wp15.pdf [Accessed 29/11/09].

HMSO (1990A). *Town and Country Planning Act 1990*. HMSO, London.

HMSO (1990B). *Planning (Listed Building and Conservation Areas) Act 1990*. HMSO, London.

HMSO (1994). *Criminal Justice and Public Order Act 1994*. HMSO, London.

HMSO (1995). *Town and Country Planning (General Permitted Development) Order 1995*. HMSO, London.

HMSO (1998). *Crime and Disorder Act 1998*. HMSO, London.

HMSO (2002). *Police Reform Act 2002*. HMSO, London.

HMSO (2006). *Police and Justice Act 2006*. HMSO, London.

ICO (2008). *CCTV Code of Practice 2008*. Information Commissioner's Office.

KUO, F. (1998). Transforming inner-city landscapes; trees sense of safety and preference. *Environment and Behavior* **30**, 28–59.

KUO, F. AND SULLIVAN, W.C. (2001). Environment and crime in the inner city: does vegetation reduce crime? *Environment and Behavior* **33**, 343–367.

LANCASHIRE EVENING POST (2007). *Council 'wastes' £115 000 on CCTV Cameras*. 25th March 2007. [Online] Available at: http://www.lep.co.uk/preston-ribble-valley/Council-39wastes39-115000-on-CCTV.2146754.jp [Accessed 18/04/09].

LARSEN, K. (2009). Orwellian state of security. *Info Security*, September/October 2009, 16-19.

LUTON TODAY (2008). Twelve trees chopped to make clear view for CCTV cameras. *Luton Today* 17 July 2008. [Online] Available at: http://www.lutontoday.co.uk/googlesearch.aspx? [Accessed 18/04/09].

MCCAHILL, M. AND NORRIS, C. (2002). *CCTV in London*. Urban Eye June 2002.

MAGILL, P. (2008). Trees stopping CCTV cameras seeing Nelson villains. *Lancashire Telegraph* 15 October 2008. [Online] Available at: http://www.lancashiretelegraph.co.uk/news/pendle/nelson/3759445.Trees_stopping_CCTV_cameras_seeing_Nelson_villains/ [Accessed 18/04/09].

MICHAEL, S.N., HULL, R.B. AND ZAHM, D.L. (2001). Environmental factors influencing auto burglary. *Environment and Behavior* **33**(3), 368–388.

MILLER, R. (1997). *Urban Forestry: Planning and Managing Urban Greenspaces*. Second edition. Prentice-Hall, New Jersey.

NIELAN, C. (2010). *Capital asset value for amenity trees*. London Tree Officers Association.

NUFU (2005). *Trees Matter! Bringing Lasting Benefits to People in Towns*. National Urban Forestry Unit.

ODPM (2002). *Living places: cleaner, safer, greener*. ODPM, London.

ODPM (2004). *The planning system and crime prevention*. ODPM, London.

ROBINSON, P. (2009). *Wrexham's Big Brother CCTV System most Successful in Wales*. North Wales Newspapers. [Online] Available at: http://www.leaderlive.co.uk/news/83317/wrexham-s-big-brother-cctv-system-most-successful-in-wales.aspx [Accessed 02/03/10].

TALBOT, K. AND KAPLAN, R. (1984). Needs and Fears: the response to trees and nature in the inner city. *Journal of Arboriculture* **10**, 222–228.

TREES AND DESIGN ACTION GROUP (2010). *No Trees, No Future. Trees in the Urban Realm*. Trees and Design Action Group.

ULRICH (1984). View through a window may influence recovery from surgery. *Science* **224**(4647), 420–421.

WEBSTER, C.W.R. (2009). CCTV policy in the UK: Reconsidering the evidence base. *Surveillance & Society* **6**(1), 10–22.

# A review of current research relating to domestic building subsidence in the UK: what price tree retention?


## Abstract

The Association of British Insurers reports that UK domestic property insurers receive around 35 000 domestic subsidence claims in a normal year, and settle them at a cost of around £250 million. In a hot, dry year, the number of claims can increase significantly. These are termed 'event' years. For example, in 2003 the claim count exceeded 55 000 and costs increased to £400 million – an increase of just over 60%. It is estimated that vegetation (primarily trees) accounts for 70% of valid claims in event years.

Unfortunately, there is often conflict between municipal arborists charged with administering statutorily controlled trees in the urban environment and the insurers of houses built on a clay sub-soil. The perceived threat of subsidence leads to polarised views from the various parties, stakeholders and interest groups.

Insurers may seek tree removal as a permanent and economic claim resolution. The Local Authority Arboricultural Officer may prefer insurers to pay for the house foundations to be deepened and implicated trees left in place. As this debate continues, on occasion ending in legal action, the homeowner can feel sidelined, watching their home deteriorate as the various interest groups take their stand. With this conflict in mind, how do concerned parties address the vision of the Mayor of London that seeks to expand London's tree cover 5% by 2025? Can insurers be seen as a force for good in contributing to maintaining urban greening?

Current research being undertaken by the Clay Research Group (CRG) and OCA UK Ltd seeks to contribute to a balanced resolution to this problem. The CRG, by linking with academics from various disciplines, has several studies under way to test new methods of undertaking the investigation and repair of subsidence damaged houses. It is anticipated that data collected can be used to support those wishing to retain trees in the urban environment.

This paper concludes by exploring the need for a policy framework built between the Association of British Insurers (ABI), Local Government Association (LGA), The Public Risk Management Association (ALARM), Communities and Local Government (CLG), Trees and Design Action Group (TDAG), Subsidence Forum and research bodies such as the CRG and OCA, so that innovation and a collaborative approach to solving those occasions when trees are implicated in indirect property damage can be established.


## Introduction

The Lord Mayor has suggested that London will need more trees to be planted by 2025 in order to mitigate the 'urban heat island effect'. It is estimated that there are *c.* 6 million trees in the London Boroughs, providing around 20% of canopy cover by total geographical area. The proposed increase adds 5% extra canopy cover, which equates to around 2 million extra trees planted.

The pursuit of sustainable urban greening is a concept supported by all political parties. Ebenezer Howard (1902) believed fervently that the best attributes of town and country life could be joined in the Garden City. He hoped that both 'may be secured in perfect combination'. We know the vision of Howard to establish and sustain tree-lined streets in Letchworth and Welwyn was not new. Planners and other groups have been striving to sustain trees and beautify our urban areas for more than a century.


**Keywords:**

climate change adaptation, environment, subsidence, sustainability, urban heat island, urban greening



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Insurers have an interest in this proposal as around 70% of domestic subsidence claims are attributable to vegetation-induced clay shrinkage (Driscoll and Skinner, 2007). The number varies considerably with temperature and location and will be higher in long, dry summers, reducing in mild years. There will be a greater proportion of such claims in areas where there are shrinkable clay soils, good tree cover and a mature housing stock. Ward (1947) reported that 'The majority of claims occur in London due to the high density of houses with shallow foundations built on highly shrinkable clay soils.'

Domestic property insurers have an interest in any significant increase in the urban tree population and need to be part of the development of a policy led approach which ensures that tree cover is maintained and increased responsibly. For balance, we must also recognise the myriad of other reasons which lead our municipal authorities to remove trees and which apparently have caused a far greater numerical loss of canopy than tree loss related to subsidence claims.

The London Assembly's (2007) review of their street trees in May 2007 provided the emotively titled *Chainsaw Massacre* and this was widely disseminated as an anti-insurer piece of work. In fact, from the population of trees felled over a five-year period only 5% were felled because they were implicated in causing damage to domestic properties. The majority of trees were felled to comply with Health & Safety requirements:

- trees removed over the previous five years 39 924
- trees removed because of subsidence claims 2034

This conflict is an inappropriate way of resolving differences when seeking to retain such a valuable asset. The benefits and attributes of trees in our cities in helping to combat the urban heat island effect are well recognised and agreed by all.

This debate continues against a backdrop of climate change. Certain species of tree will suffer more from an increase in temperature and soil drying than others. Those that survive may do so by increasing their rooting zone, drawing moisture from a wider area, thus threatening more buildings.

The Clay Research Group's (CRG) current research programme is directed towards resolving this debate by exploring a variety of techniques that will allow trees to be retained and to reduce the threat of root-induced clay shrinkage in certain instances. The project has two elements. First, determining the spatial distribution and the depth of moisture uptake of mature trees. The second is the installation of harvesting chambers to reduce water demand by combining a variety of techniques including partial root drying (PRD), which is aimed at triggering the production of hormones combined with simple rehydration of the soil.

As background to tree physiology and the hormonal regulation of transpiration the work of Prof. William Davies and his team at Lancaster University has been particularly valuable in explaining the 'root to shoot signalling system' (Wilkinson, 2002). The technique is aimed at raising the pH within the xylem of a tree to promote the effectiveness of abscisic acid (ABA) – a naturally occurring stress hormone triggered by drought conditions – in the leaf apoplast. The function of this hormone is stomatal regulation and the conservation of water.

Whether ABA is effective depends not simply on concentrations but also the pH of the cell, which determines its receptiveness. That is to say, high levels of ABA do not ensure they will be active or effective (Sauter *et al*., 2001; Sharp and Davies, 2009). The objective is to use PRD (Stikic *et al*., 2003) to trigger a reduction of the stomatal aperture in dry periods and the duration of opening, leaving the tree healthy and undamaged whilst reducing transpiration. Carbon fixing takes place over a shorter cycle. PRD is a technique whereby one half of the root system is watered, while the other is not. Stikic cites the work of others (Loveys *et al*., 2000) when he says 'PRD treatment increased xylem sap ABA concentrations and pH, and as a result, stomatal conductance was reduced. In addition, there was a reduction in the cytokinin content in roots, shoot tips and buds'. Cytokinins are a class of hormone known to regulate root and shoot growth. The combined increase in ABA and reduction in cytokinins is therefore favourable in terms of water conservation.

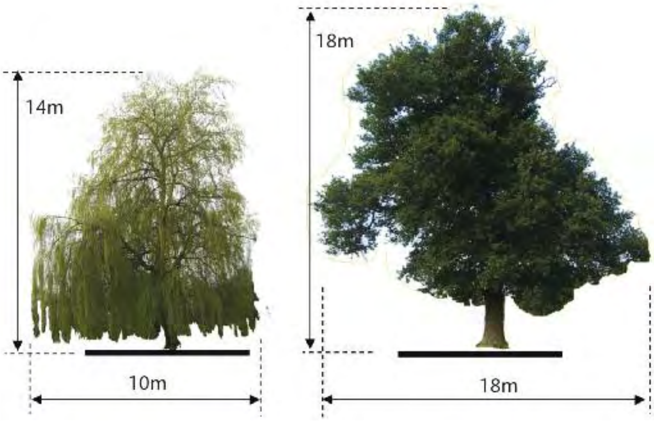
It is suggested that PRD helps when the dry roots produce ABA and the watered zone provides the vehicle to transmit the hormone to the xylem. This is a technique that has been used for crop propagation in dry countries with success. Clearly, however, there is a huge difference between crops grown under propagation conditions and street trees in an urban landscape.

The current research will we hope lead to the retention of the urban street scene and reduce conflict between various interest groups. Any solution has to be sustainable and environmentally acceptable and the cost has to be reasonable in the context of current expenditure resolving this category of claim.

# Materials and methods

Data was gathered from a 40.5 ha research site in north London by monitoring ground movement beneath a single mature willow and an oak tree (see Figure 1).

Figure 1 The subject trees and their proportions. Willow (weeping): *Salix x sepulcralis* 'Chrysocoma' and oak : *Quercus robur*. The oak is in a row of similar aged trees at 20 m spacing on a grass playing field. The willow is sited in the garden of a detached house on a gently sloping site in north London. Latitude 51.662 and longitude −0.326.



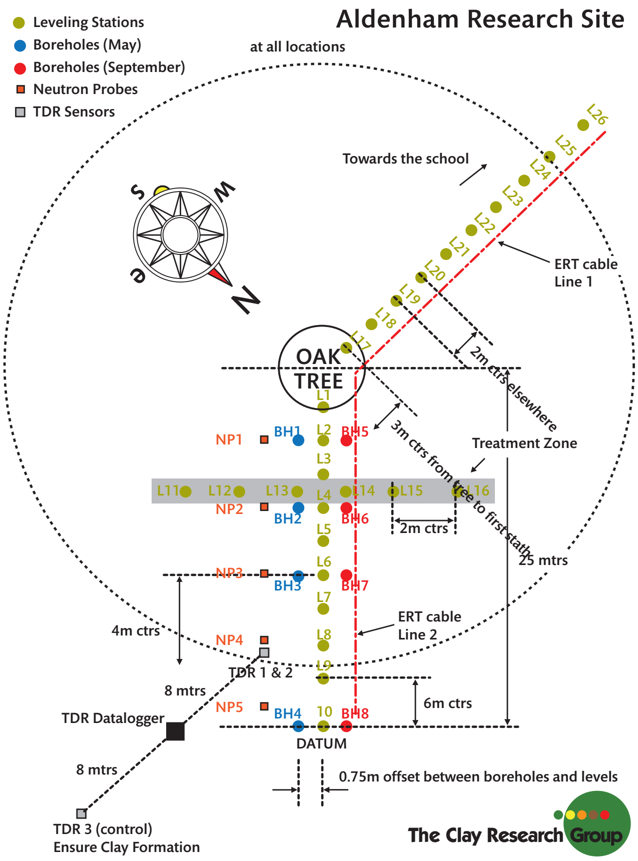

Academics were invited to use the site to complement research that they were undertaking elsewhere and to share any output.

Dr Clarke and Dr Smethurst from Southampton University have been researching the impact of climate change by gathering data from stations across the UK. They took periodic measurements of soil moisture from the site of the oak tree using a neutron probe, commencing in August 2006 with a final reading in August 2007. The distribution of the probes is shown in Figure 2. Five probes were installed to a depth of 3.8 m below ground and spaced 5 m apart with the first situated 5 m from the tree.

Dr Cassidy and Dr Jones from Keele University explored the use of electrical resistivity tomography (ERT) to measure moisture change in fine-gained soils (Jones *et al*., 2010). In addition, time domain reflectometry (TDR) sensors were used to measure change in moisture, and data has been wirelessly transmitted to the supervising engineer. TDR sensors measure volumetric moisture content by responding to changes in the dielectric constant of the surrounding soil. These changes are converted to DC voltage virtually proportional to the soil moisture content.

Telemetry – the transmission of data from buried sensors installed on site via the web to the office – avoids the need for frequent and disruptive visits to site.

Figure 2 Layout of instrumentation and levelling stations at the site of the oak tree. ERT cables are shown as red dotted lines, precise level stations are green, neutron probes orange, TDR sensors and dataloggers black and boreholes, red and blue.




A weather station was installed in 2007 to determine the correlation between moisture change and ground movement. Soil moisture deficit (SMD) data was obtained from the Meteorological Office.

Ground movement resulting from moisture content change was measured using precise levelling from over 26 stations situated either side of the oak and willow trees.

Levelling has the advantage of measuring the combined effect of the various elements – climate, trees, soil mineralogy and moisture uptake – over time across the root systems.

Away from the research site, trials on 21 domestic subsidence claims have been established primarily on London Clay soils. All of the claims have been characterised by their complex nature and a history of recurrent problems related to root-induced clay shrinkage. Not all involve the same species of tree but a large proportion was oak.

Water harvesting has been used in each case and has delivered some initially encouraging results. Harvesting takes the form of excavating a trench about 2 m away from the damaged section of the house, to a depth of 1 m.

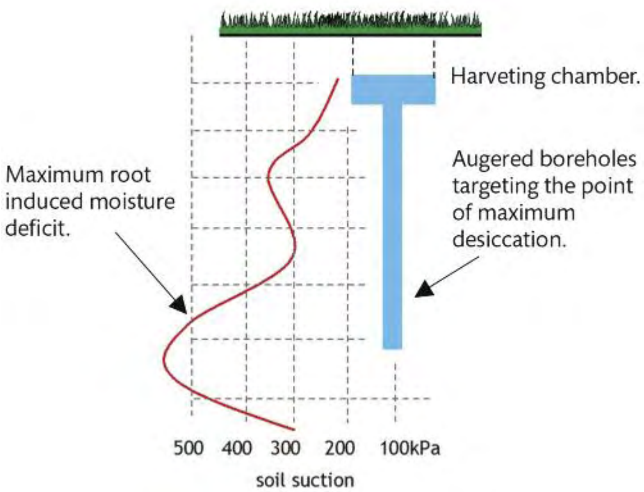
Augered holes are drilled through the bottom of the excavation to target the zone of maximum moisture deficit. This can be determined by a variety of soil testing techniques – see neutron probe data as an example, Figure 6 – or on site using a penetrometer. For mature trees this is usually around 1.8 m below ground but varies with species and climate. The depth is designed to ensure water is deployed at the point where it delivers maximum benefit, avoiding wastage from run-off and loss by evaporation.

The bores were filled with a mixture of clay, sand and lime. This produces a soil with a low plasticity index (the measure of the shrink/swell properties of a clay soil) and regulates the flow of water, avoiding saturation of the surrounding ground, but releasing water as the negative porewater pressures in the soil increase. Lime is added to raise the pH of the soil locally.

Proprietory harvesting chambers are then installed, wrapped in a tough, root-resistant membrane. The general arrangement is shown in Figure 3.

Rainwater is collected from the roof of the damaged property into the harvesting chambers with appropriate measures to cater for overflow and ventilation.

Figure 3 Diagrammatic view of the harvesting chamber feeding a series of augered boreholes that target the zone of maximum root activity. All available rainfall gathered from the rainwater downpipes etc. is fed into the chamber and the drainage is modified to ensure surplus run-off to the main drains to avoid over-flow together with a venting facility.




The project is directed to applying water harvesting in the urban environment with mature trees nearby. The challenge is to understand the benefit over a period of time. How do different species of tree respond for example, and is it a robust and sustainable solution in cases where root-induced clay shrinkage has caused damage to nearby buildings.

Precise levels have provided an assessment of moisture uptake by the tree sufficient to cause ground movement (i.e. ignoring uptake of unbound soil moisture) over time. This has been linked with climate and SMD data and has led to the production of a climate model as well as providing valuable information regarding a possible method of rehydrating desiccated soils.

# Results

## Water uptake

In contrast to the more usual view of root-induced desiccation where the ground movement assumes a saucer-like profile with maximum movement close to the tree, ground movement profiles of oak and willow at the research site have demonstrated an increased moisture uptake (and hence greater ground movement) some distance from the tree.

The soil directly beneath the canopy dries over time to produce a persistent moisture deficit and the peripheral roots account for the majority of moisture uptake (see Figure 4). Ground movement produces a regular signature in both dry and wet years, varying only by amplitude. In a relatively dry summer (2006 in the example below) movement peaks at 60 mm of subsidence to the right of the image, and reduces to 48 mm in the wetter summer of 2007.

Electrical resistivity tomography (Figure 5) has provided visual evidence of moisture change over time for both the oak and willow (Jones *et al*., 2010). In addition we have data from the unpublished results of an earlier investigation undertaken by Dr Ron Barker at Birmingham University in 2001, showing moisture change beneath a sycamore tree on boulder clay deposits, comparing winter and summer values.

Neutron probe measurements (Figure 6) undertaken by a team from Southampton University have provided important information regarding the depth from which moisture is abstracted.

This data relates to the oak and willow at the research site and provides valuable information for subsidence practitioners in terms of knowing at what depth to target their investigations to obtain evidence of root-induced desiccation. Previously it had been assumed that roots dry soils 'top down'. The neutron probe data (supported by the

Figure 4 Seasonal ground movement (subsidence) at the site of the willow noting the difference in claim notifications between a dry year (2006) and wetter years (2007 and 2008). The profiles reveal increased activity at the root periphery associated with moisture uptake and a regular signature in both wet and dry years which continued to be noted in subsequent years. The x axis represents the distance from the willow (central in all illustrations and marked by dotted line) and the y axis is the amount of ground movement that has taken place in millimetres.

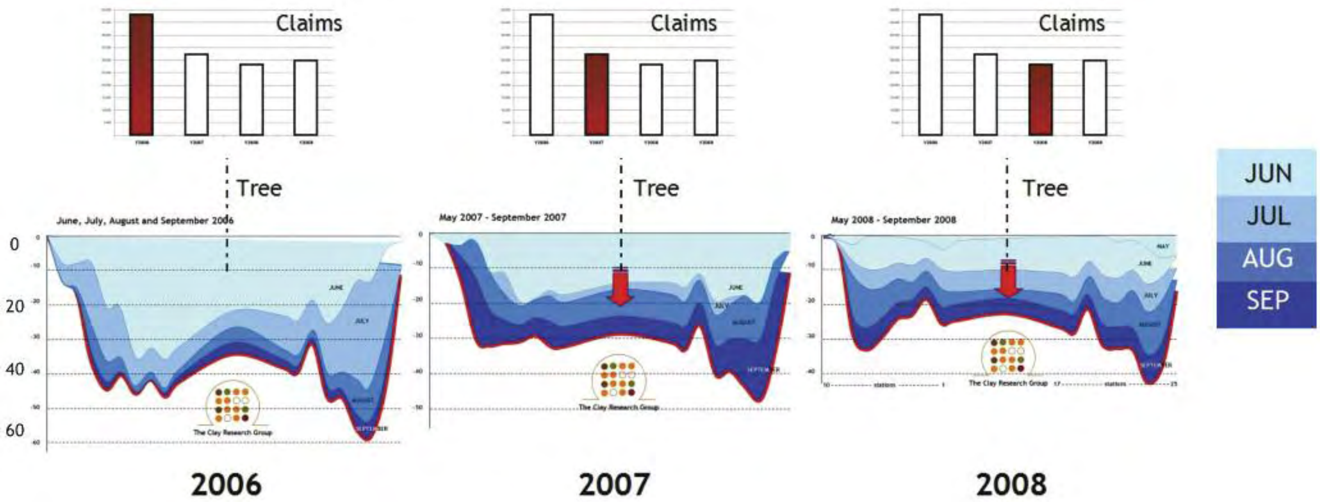



Figure 5 Moisture change beneath an oak tree situated in the Midlands (not from the research site) as revealed by ERT imagery. Changes in moisture content over a few months are clearly illustrated. The zone from which roots are extracting moisture is shallower than in the London Clay at the research site possibly due to the presence of superficial strata of boulder clay overlying the Mercia Mudstone. The lateral extent of drying is approximately equal to the tree height in this instance. Provided by Dr Ron Barker, Birmingham University – personal communication.

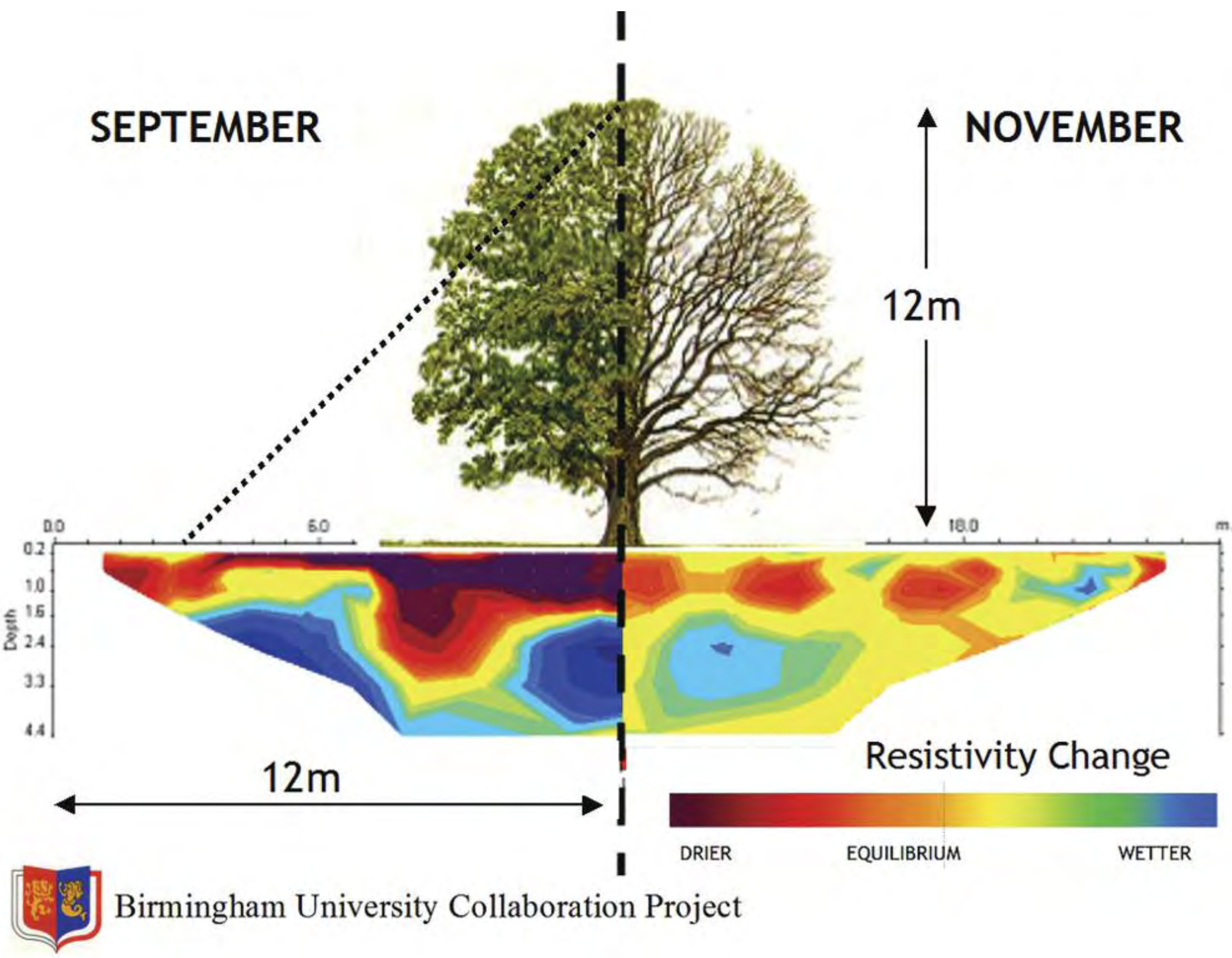
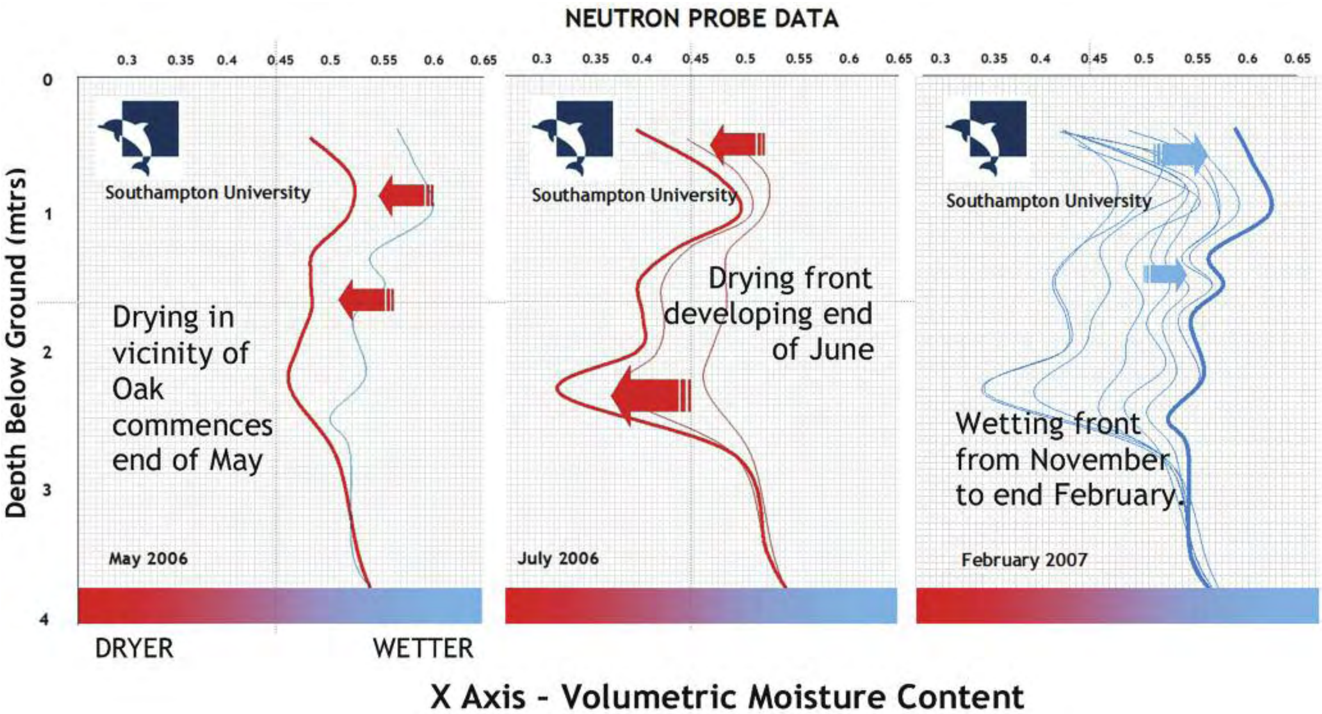


Figure 6 Moisture change measured at the site of the oak tree at the research site in north London by Southampton University using the neutron probe and revealing maximum uptake associated with root activity at around 2 m below ground. Superficial drying due to evaporation is revealed at ground level down to 1 m.



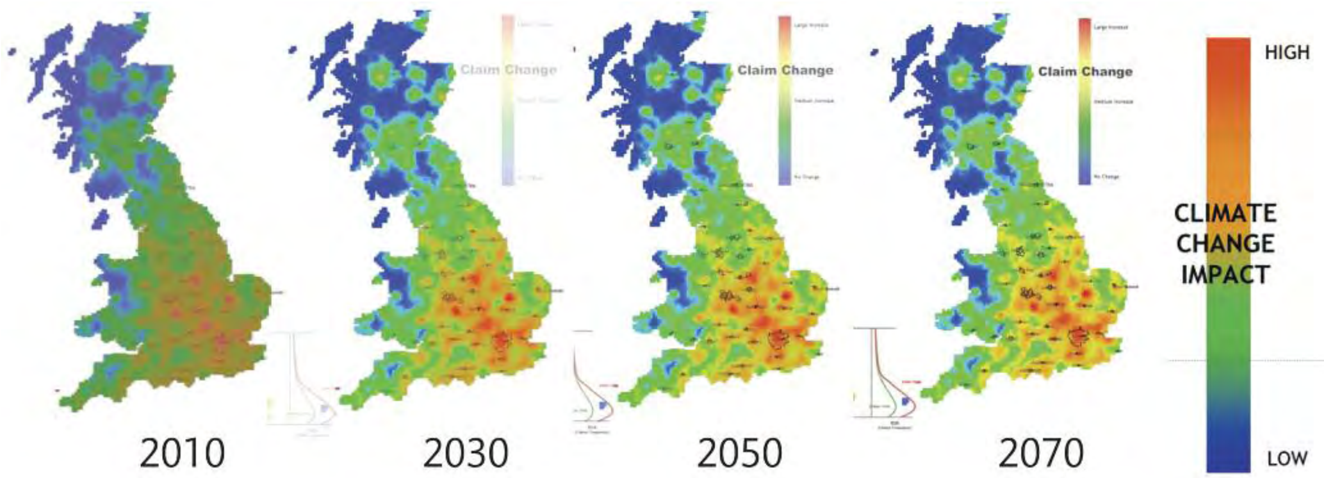

results of actual soil investigations), indicates that soil sampling is likely to deliver better evidence at around 2 to 2.5 m below ground level when investigating mature trees.

## Climate

Mapping the geographic distribution and shrink/swell properties of clay soils from site investigations has assisted in producing the maps in Figure 7, which reveal the impact on claim numbers of temperature increases associated with climate change. Root-induced clay shrinkage (as the name indicates) is only a problem where there are shrinkable clay soils.

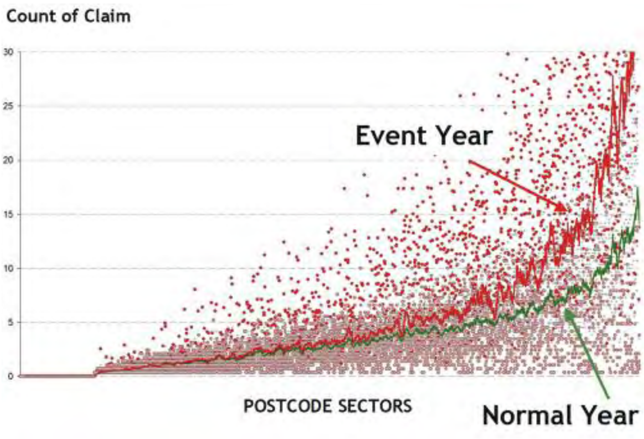
This qualitative view of the UK indicates where trees are likely to cause damage and can be adjusted by actual temperature increases to deliver estimates of claim numbers by comparing an event year with a normal year.

Figure 7 CRG model of climate change impact in relation to root-induced clay shrinkage subsidence claims.



Matching claim numbers (see Figure 8) with temperature anomaly data (see Figure 9) provides some indication of the effect that temperature increases and reduced rainfall may bring. Figure 8 illustrates that numbers increased where there are clay soils, and the greater the shrink/swell potential, the greater the difference between the profiles.

Figure 8 Taking industry figures of subsidence claim notifications and plotting them against postcode sectors, the difference between what insurers regard as 'normal' and 'event' years can be related to changes in temperature and rainfall to model future trends resulting from climate change. Around 20% of postcode sectors lie on shrinkable clay (these are identified by the divergence in numbers to the right of the graph) and they are the areas where trees are more likely to cause damage.




Anomaly data (see Figure 9) uses 2007 as a baseline for a normal claims year and plots the anomaly in temperature and rainfall with 2006 (an intermediate year for claims) and 2003 – an event year.

# Discussion

This study explores some of the work currently undertaken to improve our understanding of the interaction between clay soils, trees and climate in relation to domestic subsidence in the UK.

## Water uptake

We have an improved understanding of how roots from mature trees can exert an influence at a distance away from the tree and the depth from which moisture is drawn. The suggestion that ground movement increases with distance, as has been demonstrated in this study, is new.

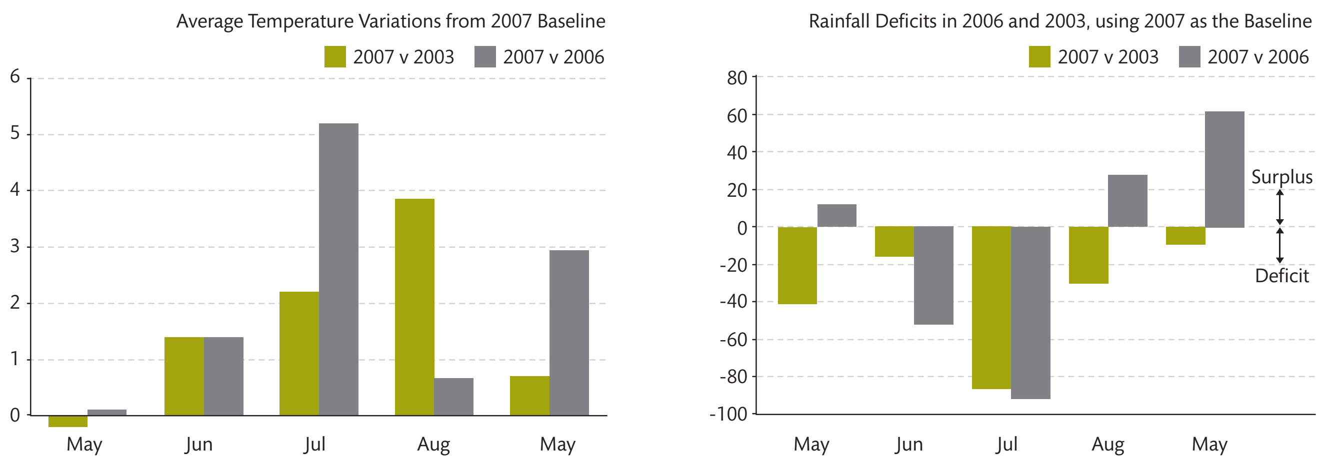
This provides valuable information to engineers when investigating cases of root nuisance regarding understanding the pattern of distress and the depth from which samples are to be extracted – that is, testing soils at 1 m below ground is less likely to deliver a result than testing at 2 m. It is also important in designing any form of soil intervention technique.

An improved understanding of root activity determined by precise levelling has provided guidance on where to target the 'water injection' from the harvesting chambers and with regards to subsidence, if the trials are successful, it will have a beneficial impact not only for insurers, but also homeowners and local authorities.

## Climate

The research has produced a climate model that will assist insurers and others to develop a strategy for the future. It improves our understanding of where claims are likely to

Figure 9 Temperature and rainfall anomaly data using 2007 as a baseline for a normal claims years and plotting change for two event years, 2003 and 2006.



arise geographically, and the influence of temperature and rainfall on claim numbers and indemnity spend.

By modelling the change in claim numbers resulting from an increase in temperature, we can begin to understand the impact on housing stock of a tree planting regime. As we reported in the introduction, the increase in subsidence claim numbers in dry years is associated with the presence of trees on clay soils and an increase in the tree population will have a bearing on costs to insurers, homeowners and local authorities.

Clarke *et al.* (2006) suggest that 'in 50 years time, every summer day will replicate the conditions we see now in an event year'. By adding 5% (the planned increase in tree canopy planned as part of the urban greening programme) we can model the financial impact over time.

## Ground treatment

This improved understanding of the distribution of rooting, ground movement and depth of moisture abstraction described leads to the current phase of research involving the installation of harvesting chambers that might allow tree retention in certain cases. The technique, if successful, will allow the prompt settlement of some domestic subsidence claims for a relatively modest sum of money.

Water harvesting has been installed on a total of 21 houses that have suffered damage resulting from root-induced clay shrinkage. Many had suffered recurring damage linked to a variety of mature trees, predominantly oak. Water harvesting was applied on the first claim early in 2008 and, so far, there has been no notified recurrence of damage at any of the sites.

Hydrating a small section of the root zone while another portion is growing in dry soils beneath impervious tarmac and paving, replicates (in part) a technique known as partial root drying (PRD). This method, used primarily for fruit production, is also thought to enhance the effectiveness of the hormone ABA.

The objective of alleviating root-induced clay shrinkage damage to domestic dwellings using water harvesting is not to satisfy the water demand of the tree. Water harvesting has been installed to reduce the water deficit in the vicinity of damage. Watering-in offers multiple benefits. The obvious ones are (a) adding moisture to the soil causing it to recover to its former level, (b) raising the pH of the water in the xylem which in turn (c) increases the effectiveness of ABA at the apoplast. This leads to closure of the stoma and a reduction in transpiration.

The more traditional approach to raise the soil pH would be to add lime to the soil. Harvesting offers the potential (but as yet unproven) advantage of delivering water quickly and efficiently to the desiccated soil. Adding lime to the soil without watering would not help in dry weather and would provide little benefit in terms of rehydrating a desiccated soil 2 m below ground level.

Rehydration using harvested water does not have to return the soil to field capacity in the summer. It has to be sufficient to emulate a SMD accompanying what insurers regard as a 'normal' year for subsidence claim numbers. For example, if the SMD for grass cover is 120 mm in a dry year with a high claims frequency, the harvesting chambers would have to provide sufficient water to reduce this by 15–20% to emulate a 'normal' claims year. The harvested water is directed to a specific location and has to reduce desiccation – not remove it altogether. The available water is increased by a factor of 4 (i.e. the average area of the roof compared with that of the harvesting chamber) for the average domestic dwelling in the area of desiccation by diverting roof rainwater run-off into the chambers. The objective is to reassure the homeowner by providing a robust and lasting solution whilst reducing the likelihood of litigation between insurers and local authorities.

The study has provided information on how much water is consumed by mature trees by using volumetric estimates based on ground movement by month. It has identified (a) the ground movement that takes place as a result of moisture loss, (b) the differences between dry and wet summers and (c) the depth that any treatment has to be applied to deliver maximum benefit, quickly.

The project is at an early stage. Measuring change produced by mature trees is a much slower process than work in the field of crop science. The genetic factors determining the influence of hormones individually or in combination will almost certainly be very different. The involvement of physiologists from the biosciences to measure tree water uptake over a period of time and any associated hormonal production would be invaluable.

# Conclusions

Britain's Victorian legacy of tree-lined streets continue to survive pressures applied by a wide variety of operators opening up our public footpaths as well as our demands for the information technology super highway being readily available.

The pressure from subsidence-related insurance claims is relatively small compared to the extent of utility excavations permitted. Nonetheless, insurers have a financial and environmental interest and should be allowed a voice in developing the strategy for London greening.

The CRG and OCA UK Ltd will continue to research the interaction between vegetation and fine-grained soils under different climatic conditions and share data and resources with other interest groups in this important area of asset/liability land management.

The various bodies who are doing significant work in their own interest areas should join together with the ABI, the Subsidence Forum and LGA to establish a joint approach to formulating a comprehensive pan-sector Code of Practice covering claims of the sort described. Innovation and co-operation between interested parties will help to resolve any conflicts and should be based on sound scientific peer-reviewed research in relation to the influence of trees on their surroundings.

## References


CLARKE, D., SMETHURST, J. AND POWRIE, W. (2006). Seasonal changes in pore water pressure in a grass covered cut slope in London Clay. *Geotechnique* **56**(8), 523–537.

DRISCOLL, R. AND SKINNER, H. (2007). *Subsidence Damage to Domestic Buildings*. BRE Trust.

HOWARD, E. (1902). *Garden Cities of Tomorrow.* Reprinted in 1965 by Faber and Faber.

JONES, G.M., CASSIDY, N.J., THOMAS, P.A., PLANTE, S. AND PRINGLE, J.K. (2009). Imaging and monitoring tree-induced subsidence using electrical resistivity tomography. *Near Surface Geophysics* **7**, 191-206.

LONDON ASSEMBLY (2007). *Chainsaw Massacre: A review of London's street trees.* A report from the London Assembly Environment Committee. Greater London Authority.

LOVEYS, B.R., DRY, P.R., STOLL, M. AND MCCARTHY, M.G. (2000). Using Plant Physiology to Improve the Water Use Efficiency of Horticultural Crops. *Acta Horticulturae* **537**, 187-199.

SAUTER, A., DAVIES, W.J. AND HARTUNG, W. (2001). Long distance abscisic acid signal in the droughted plant: the fate of the hormone on its way from root to shoot. *Journal of Experimental Botany* **52**(363), 1991–1997.

SHARP, R.G. AND DAVIES, W.J. (2009). Variability among species in the apoplastic pH signalling response to drying soils. *Journal of Experimental Botany* **60**(15), 4363–4370.

STIKIC, R., POPOVIC, M., SRDIC, M., SAVIC, D., JOVANOVIC, Z., PROKIC, I.J. AND ZDRAVKOVIC, J., (2003). A new technique for growing plants that saves water and improves the quality of fruit. *Bulgarian Journal of Plant Physiology.* Special Issue 2003, 164-171.

WARD, W.H. (1947). The effects of fast growing trees and shrubs on shallow foundations. *Journal of the Institute of Architects*, pp. 3–12.

WILKINSON, S. AND DAVIES, W.J. (2002). ABA-based chemical signalling: the co-ordination of responses to stress in plants. *Plant, Cell and Environment* **25**, 195–210.

# Closing address

## Urban/rural ecology in the transition to the 'ecological age'

**Peter Head**

Former Chairman of Global Planning and currently consultant to Arup

It's a great pleasure to be here with lots of friends in the audience and I hope what I can do – and I know you've had a very busy two days – is to try and bring some of the threads together and actually start with a global perspective on the subject.

The reason that I can do that is because in the last three and a half years, I have been asked by the Institution of Civil Engineers to do the Brunel Lecture Series. This involved someone lecturing in many countries around the world (I've actually been to 28 countries) and you can choose the subject. I thought it would be a great opportunity to do a properly researched project into answering a number of fundamental questions: Is it possible for nine billion people to live sustainably on the planet in 2050 – that is the number we'll have and, incidentally, if you didn't know, it's the maximum number probably that we'll ever have. If it is possible, what policies and investments are needed to get to that point of being a sustainable condition? Today, I'm going to collect together a lot of the evidence that I produced, a lot of the feedback I've had from 28 countries, and talk about the role of trees and forestry in relation to delivering a transition to what I call the 'ecological age'. Now I stole that title from Hu Jintao from China who actually said, three presentations ago at the annual conference in China, that he wanted to take China to the ecological civilisation, and I'm going to tell you how I define that in a minute. Incidentally, if you want to find the material I produced you can go onto the Arup website and find written material and so on.

Now, in order to do that research I was able to use a lot of background research that Arup has done itself into the drivers for change. You may have seen the drivers for change cards, and if you haven't, you can get hold of them. There's a lot of global research behind each of these drivers and what the world is trying to do to address each of these major issues. I'm going to show an example later on in my presentation of how green infrastructure can address some of these principal issues that we're facing on the planet.

My motivation here is one of really worrying about climate change. I was at a conference in Hong Kong just before Christmas when we were told there is now a 50% probability of human catastrophe in 2070 because we're now on a trajectory of three to four degrees of warming by 2070. If that happens, there is a 50% probability of getting runaway climate change. I have three grandchildren who will be alive then, all being well, and I desperately worry about the sort of life that they may have in 2070 if we don't do something really quickly. We were told that we really only now have 10 years to get ourselves onto a trajectory of reducing carbon emissions globally. So, that's one of my main concerns and motivations. The other concern I have, of course, is the amount of land we have available to support human life: the ecological footprint. In reality, in the last 100 years, we've gone from having about eight hectares of land per person to only having about two hectares of land per person to provide our energy, to provide our water, to absorb waste, and to provide our food. By 2050 we're going to have one and a half hectares per person, and we cannot survive unless we get ourselves organised to manage that one and a half hectares per person in the best possible way to have a low carbon resource-efficient life. So, for me, the two things go together very clearly, and agriculture and forestry are key parts of that equation.

It seems to me that the impact that we've had on the land through agriculture and deforestation lies at the heart of the problem that we're facing and the amount of fossil fuels that we're now putting into agriculture. The sort of crazy stuff you see in the southern part of Spain – where the whole of southern Spain is just about being covered over with greenhouses to grow strawberries and other things with a completely devastated water supply system – you know this really is a completely unsustainable approach to agriculture of all kinds.

Then, obviously, there's deforestation which is creating flash flooding; all the things you know very well. Many of you must have seen the John D. Liu films of the Loess Plateau in China, and Reforestation of the Rwandan and Ethiopian hills? If you haven't, I have just got a small snatch [video] of what has been going on in China and, for me, this is really inspirational. The fact that the upper end of the Loess Plateau has been reforested and terraced to actually bring agriculture back, not by massive machinery and civil engineering, but by local people actually working the land themselves. Local people working out how to bring water back through forestation which can then come into agricultural productivity. This transformation has been achieved in only 15 years in hundreds of square kilometres of land. So, it does seem to me that the human race is capable of bringing ourselves back to what I call 'the ecological age system' and bringing back the biodiversity that obviously goes with it.

I gave a presentation in Edinburgh for the Patrick Geddes Society. Patrick Geddes is still one of the most important and influential urban planning people in the UK, and this was his philosophy: that this is basically a green world – we're pretty insignificant really. It's a green world that's dependent on leaves and we have this strange idea that money makes things go round, but it's actually leaves and soil that makes the world go round really and we have to understand that. It is extraordinary that Patrick Geddes promoted all of these ideas so long ago and somehow it's been lost in our urban development thinking. Now is the time; we've got to bring it back. I don't shirk from the idea that there is a spiritual-cultural issue in this because we're all descended from the history and culture of living with trees and natural systems.

So, let's get from the ethics to the hard-nosed economics. Basically, at the moment we think success is to achieve GDP [Gross Domestic Product] growth, and that GDP growth is destroying the ecosystem. That is not success, that's failure because actually we're not going to make it if we continue to do that. So, somehow we've got to get ourselves away from the idea of using non-renewable resources wastefully and polluting the planet, to the alternative economic model of actually using renewable systems efficiently. If we do that, then our economic model can be one that's successful and the ecosystem can recover, and indeed we can accelerate its recovery through that process. So, we don't have to give stuff up, we just have to use renewable systems and to use them efficiently and that is the essential paradigm shift for the ecological age – it's one from owning things to actually having services from everything around us.

I'm an engineer, so I like equations... so this is the equation for the ecological age: average reduction of 50% of carbon dioxide emissions from 1990 levels by 2050 (which is 80% in the UK for our share of that average), getting to one and a half hectares per person ecological footprint, and then allowing human development to actually accelerate again. I genuinely believe that if we stop owning things we don't need, and we have a much more resource efficient lifestyle, we'll actually have a lot more money to spend on health and education. Crazily, at the moment, we seem to think we can't afford health and education yet in reality we're spending money on all sorts of stuff we don't actually need if we organised ourselves better. So, actually what this means in low to middle income countries is the paradigm shift of eco cities, which I'll touch briefly on in a minute, and in middle to high income countries like Britain it's a matter of retrofitting. It is a matter of looking at urban and rural systems as a connected set of systems including forestry both inside and outside the city. There is an ethical dimension to this, for the very first time on the agenda at COP 16 (Mexico 2010: United Nations Climate Change Conference), which is that the world now recognises that those that have created climate change actually have to start funding adaptation to climate change in developing countries. This is an ethical issue that we've got to do that and, of course, the amount of money that is now being pledged to do that can be used for things like forestry because forestry will have a very, very beneficial effect of reducing flooding of the land, of improving the carbon sequestration issues and actually improving human health and so on. So, actually, forestry for me should be a major part of adaptation investment in developing countries globally, and I'm not sure that it is at the moment.

I believe that the only framework that's going to get us to the answer quickly enough is to use biomimicry. I'm sure many of you know about biomimicry, and of course the tree is the ultimate biomimicry example. It's what Janine Benyus (1997) uses in her book *Biomimicry: Innovation Inspired by Nature*. She uses the Redwood Forest as the ultimate diverse system using waste as a resource, etc. So, not only is the tree the perfect example, or a forest a perfect example, of biomimicry but it also tells us all the things that we need to do in order to go forward. This means resource efficiency in managing food, raw materials, energy and water as efficiently as we can.

Very briefly, on energy, the really interesting thing is that the European Union and Japan have about half the energy consumption per capita of the USA and Australia, and China (with its energy efficient targets) is now targeting about half the level of energy consumption per capita when they reach the same level of GDP as we have. The German Chancellor in the climate change action plan that's been brought forward in Germany is also targeting a reduction to about half of the current energy consumption in Germany. So, the world is converging on an energy consumption per capita, which is where China is on that graph [refers to slide], which is an order of magnitude different from the USA and, therefore, the transition to the ecological age in the USA is a really, really troublesome thing.

In Europe, there is the idea of creating a super grid that enables energy to be drawn from renewable resources all over Europe including concentrated solar power in North Africa, which incidentally will have a very profound impact on the opportunities coming out of the current unrest. In Egypt, for example, if you take only a tiny part of the desert fringe to supply energy to Europe, that will treble Egypt's GDP. So, actually, there are tremendous opportunities out of the 'Desertec ' European proposal, but the green dots shown on this map [refers to slide] are biomass. Everywhere I go in Europe, particularly in northern Europe, the idea of using biomass as part of this story is regarded as very important. But, as you will realise now, I believe that energy from biomass should come from anaerobic digestion and not from burning it because burning it wastes heat and releases carbon back again. We need to make sure everything is sequestering carbon at the best possible way, and we're bringing the carbon back into agriculture through processes like anaerobic digestion. If we carry on using coal and gas, which inevitably we will continue, this is not going to go away by 2050, in my view. We have to make sure that we use the waste heat from power stations and we have to sequester the carbon dioxide as best as possible and the only way I can think of doing that is using algae systems. So, I'm working very hard to see if we can develop an algae approach to at least capturing maybe 40% of the emissions from power stations.

The other big issue that we're facing, which John Beddington calls 'the triple crunch', is a decreasing food supply. The fertilisers we're using are no longer able to increase food production and so food production per capita on average is now reducing and is set to continue to reduce, which of course has a terrible impact on poverty, on starvation and on food prices. The only way this can be addressed really is through looking at urban and rural systems, managing nutrients and nitrogen and phosphorus, and significantly changing our water management practices because agriculture uses about 80% of fresh water to actually work urban and rural systems together to manage water.

We only have one example of a project in China where we've done this. This was the Wanzhuang Eco City Development (near LangFang) in a very, very water-starved part of north-eastern China. There we discovered that if we use the waste water from the city to provide drip feed irrigation for agriculture for the farmers, and we use the digested sewage waste and nutrient feeds from the city, we can actually lift urban agriculture on the land that's left after urbanisation by two to three times by having at least two crops. That means, therefore, that urbanisation can increase food productivity, and that is a concept that India and China need to learn extremely quickly as long as water management is brought into the equation. So, actually, there is a paradigm shift of thinking around that, which we can come back to.

Here, I've got the drivers for change on the bottom axis [refers to graph]. I want to just briefly describe the way that Arup is currently looking at green infrastructure. Basically we're taking these social, technical, economic drivers, and we're working with them. This is actually a project example [refers to slide] of looking at all the interventions that can be made in green infrastructure in terms of swales, forestry, tree planting and so on – all the things that you've been talking about for the last two days – and then bringing those through into water supply issues, into urban food production and into delivering the actual green infrastructure that we need. This sort of integrated resource management thinking is now something that we're able to do with models including economics at a regional scale.

For me, this is now the only way forward to address this terrible crunch, and the process of anaerobic digestion, which actually basically takes the biomass and digests it into compost and nutrients, with the gas then being used for energy. This is an example from the Hammarby Development in Stockholm, which is a development of two thousand people where this is operating very successfully. People there know how much of their human waste actually enables them to drive their car every day. That's something that we have to get used to, the idea of that sort of closed looped thinking in terms of understanding exactly what we're doing from a community level. I think there are many examples of how we can move this forward. In terms of urban development in China, this is an example of an Eco City Development that we did in Chongming Island near Shanghai. It hasn't moved forward yet, but I gather it is going to move forward now. Just to give you some idea of the green area per capita in the city that we were aiming for, we were aiming for about 27 square metres per person, which is a little bit higher than London, and so much higher than cities like Los Angeles, which only has 6.6 square metres per person.

The really important thing about green space in cities is the health benefits that accrue from it, not just physical health in terms of exercise but also mental health, and I believe that's a really important issue. Mental health benefits come from having accessibility to green space, so having green space that's distributed through the city within walking distance of every house and business rather than having a Central Park model like they have in New York where people can't access that green space every day and therefore you don't get the benefits from it. So, the distribution of resources, and actually the cultural linking of green space to the cultural root of a place is something that Feng Shui in China is very good at. I think we need to look much more carefully at the cultural links between our green space in cities and the population that live there, so it resonates for them in a deep philosophical and spiritual way. So, this is an example of applying those techniques to an Eco City plan in China that I hope, sincerely hope, will actually be implemented.

I want to briefly mention Singapore because I'm an adviser to the Singapore government. I find their approach to managing ecology in the city absolutely totally inspiring; the fact that the Urban Parks Department actually do manage the ecology of the city in an extremely sophisticated way. The university in Singapore is modelling a number of aspects of that, which is definitely the way forward. For example, if you didn't know this, they are actually trying out the introduction of dragonfly habitats into the lakes in Singapore to try and control dengue fever. Now, it seems to me that sort of integrated human health and ecology system is exactly the way we should be going to get the economic outcomes from ecological systems that are possible.

So, then, coming back to a place like London, here is a statistic (this is an analysis we've done of roof ecology, of green roofs, and other systems in London): there is a possibility of getting 100 square kilometres of green in London on the tops of buildings. This is actually a realistic proposition compared with what we have at the moment as a wasteland. A project that's probably as inspiring as any in terms of the ecological age transition is this project in Seoul in Korea where the Mayor decided to take out this dual three lane highway and replace it with a river that actually used to be there. Now, this has been done [referring to slide]. This isn't a photomontage, this is real, and this is an economic development project. They haven't replaced this road with other forms of transport; basically this is an inclusion project because now people can walk and cycle into the city to get jobs. People who don't have very much money can walk and cycle into the city and get their jobs and therefore the cost of labour in the centre of the city has gone down, the economic development has increased, the air quality is better. The congestion on that road was so great that nobody could move anyway, so the whole thing has sorted itself out economically and now more and more of these transformations have been made. The key message here is that we shouldn't build these big roads in city centres.

This is the message we're now trying to get over in India and China: that really this is not the thing to do because you'll end up taking it out again. What you should concentrate on is urban food production; taking the sewage waste and the nutrients, the collected rain water and the sunlight in the city, and growing food on a big scale. This is now being done in New York. There's a wonderful company called Gotham Greens which is now planning to grow food on the rooftops in New York in a commercially attractive way.

So, just to finish off, what I'd like to do now is to show you a short video that brings a number of these ideas together. This is actually a fictitious approach in Manchester to bringing together a lot of these ideas, and basically it is all about a deliverable transition to an ecological age by 2050 in a place like Manchester. The first thing is where we put extra public transport in. We put higher density mixed use developments to bring more people into the city so they can get to work really easily and help fund the transport, and as we put public transport into the streets to plant trees for all the reasons that you all know – for water retention, for air quality, for shading of the buildings, and then to use the buildings to gather and use energy efficiently like in biomimicry, which could be algae systems, could be photovoltaics, could be ground source heat pumps. As the buildings are retrofitted, the skins of the buildings can be replaced with passive cooling, they include green systems to cool the streets as well which reduces energy consumption. Then on the tops of buildings, again to reduce heat island effects, are not just green roofs but roof-top food production which actually creates economic benefits and local nutritious food for people working in the city, which doesn't have to have all the air miles associated with others. So, overall, this can lead to a change that would enable people to feel that they're living in harmony with the natural world. Additionally, then having information systems on your mobile phone, so for old people, disabled people and young people, when they turn up at the bus stop they know exactly when the bus is coming, so they can use public transport reliably and comfortably. And buildings can become power plants that actually can gather and use energy efficiently and power the city.

This sort of vision of a transition to the ecological age in middle and high income cities is definitely deliverable. And as part of the discussion forum that we'll have now with some audience questions, I would be very happy to describe some of the ways we're trying to take this forward on major retrofit projects in the UK.

## Reference


BENYUS, J.M. (1997).
*Biomimicry: Innovation inspired by Nature*. First edition. William Morrow.

# Appendix 1: Conference organisation

## The Conference host team was:

**Conference Chair:** Dr Mark Johnston, Research Fellow: Arboriculture and Urban Forestry, Myerscough College

**ICF Executive Director:** Shireen Chambers

**ICF Communications and Events Manager**: Allison Lock

**Additional ICF host team:** Ingrid Palmer, David Lyon, Karolina Krygowska and Thalia Bogdanou
The assistance of volunteer helpers is gratefully acknowledged.

## Steering Group organisations and representatives:

| Organisation | Representative |
|---|---|
| Myerscough College | Dr Mark Johnston (Chair) |
| Natural England | Caroline Birchall |
| Commission for Architecture and the Built Environment | Chris Edwards |
| Landscape Institute | Ian Phillips |
| Trees and Design Action Group | Sue James |
| Forestry Commission, London District | Jim Smith |
| Forestry Commission, Forest Research | Tony Hutchings |
| Institute of Chartered Foresters | Shireen Chambers |
| Royal Town Planning Institute | Trish Cookson |
| Arboricultural Association | Keith Sacre |
| Royal Institute of British Architects | Alex Tait |
| Royal Institution of Chartered Surveyors | Fiona Mannix |
| National Association of Tree Officers | Mike Volp |
| Utility Arboriculture Group | Dr Dealga O'Callaghan |
| International Society of Arboriculture | Russell Ball |
| Bartlett Tree Research Laboratories | Dr Glynn Percival |
| University of Manchester | Dr Roland Ennos |
| Ancient Tree Forum | Neville Fay |
| London Tree Officers Association | Al Smith |
| Midland/Municipal Tree Officers Association | Julie Sadler |
| **Consultative members** | |
| English Heritage | Jenifer White |
| Department for Communities and Local Government | Peter Annett |
| **Steering Group Conference programme panel:** | |
| Myerscough College | Dr Mark Johnston (Chair) |
| University of Manchester | Dr Roland Ennos |
| Forestry Commission, Forest Research | Tony Hutchings |
| Trees and Design Action Group | Sue James |
| Bartlett Tree Research Laboratories | Dr Glynn Percival |
| Arboricultural Association | Keith Sacre |

# Appendix 2: Biographies for speakers and chairs

## Janet Askew (Session Chair)

**Head of the Department of Planning and Architecture, University of the West of England, UK**

Janet is the Head of the Department of Planning and Architecture at the University of the West of England, Bristol. The department, where design and planning are integrated in research and teaching, is the UK's biggest planning school with over 1000 students studying on professionally accredited programmes. Janet has worked as a town planner in the public and private sectors in the UK and, for the past 20 years, as an academic. She is active in the professional body, the Royal Town Planning Institute, leading responses to matters pertaining to the control and management of development. Her research has mainly been concerned with the impact of regulations on planning for infrastructure, particularly in the area of telecommunications, about which she acted as an adviser to the UK government. More recently, she has led a project for the Royal Institution of Chartered Surveyors looking at planning for green infrastructure.

## Stuart Body (Speaker)

**Tree Officer, Directorate of Environment and Regeneration, Flintshire County Council, UK**

After completing a degree in Environmental Science in 1989, Stuart set out on a career in arboriculture. He obtained an NCH in Arboriculture at Myerscough College and then carried out practical work for several tree contractors. In 1991, he settled in North Wales and became a local authority tree officer, firstly at Wrexham and then, in 1996, the unitary authority of Flintshire County Council. Stuart has extensive experience of the role local authorities have in safeguarding and promoting trees including responding to evolving socio-economic factors that affect tree cover. In 2010, he obtained an MSc in Arboriculture and Urban Forestry (with distinction) at Myerscough College.

## Angela Brady (Session Chair)

**President Elect of the Royal Institute of British Architects, UK**

Over 20 years ago, Angela set up Brady Mallalieu Architects an award-winning design-led private practice specialising in contemporary sustainable design. She is a STEMnet Ambassador, a Government Equality Ambassador, Vice Chair of Civic Trust Awards and an RIAI council member. She is also a past member of CABE/English Heritage Urban panel, Design Champion of London Development Agency Board, and Trustee/Director of Building Exploratory Hackney. Angela is a founder member of RIBA's 'Architects for Change', promoting women and BAME architects in the profession. She has created and led many professional and design initiatives with RIAI, RIBA, CABE, Artsinform and Open City. Angela is well known for her media work and TV shows such as 'The Home Show' on Channel 4 and 'Building the Dream' on ITV, bringing an appreciation of architecture and design to the public.

## Dr Norman Dandy (Speaker)

**Research Scientist, Forest Research, UK**

Norman completed his PhD on international conservation politics and ethics within the Department of Politics and International Relations at the University of Leicester in 2005. Prior to that, he studied for an Earth and Environmental Sciences degree at Anglia Polytechnic and a Masters in Environmental Politics at Keele University. He has worked as a lecturer in politics and social research methods and joined Forest Research's Social and Economic Research Group in

May 2006. Norman's current research focuses on the governance of land management, with particular reference to biomass and human dimensions of wildlife. He also has an active interest in methodology.

## Dr Liz Denman (Speaker)

**School of Land and Environment, University of Melbourne, Australia**

Liz is a horticulturist who recently completed her PhD in the School of Land and Environment at the University of Melbourne. The PhD research investigated the potential to use street tree biofiltration systems to remove nitrogen and phosphorus from urban stormwater. Her major interests include the establishment and management of vegetation in urban areas and also the environmental benefits afforded by plants in the landscape.

## Dr Roland Ennos (Speaker)

**Reader in Ecology, Faculty of Life Sciences, University of Manchester, UK**

Roland is an expert on biomechanics, having first investigated animals before moving on to look at the mechanics of root anchorage and develop a particular interest in trees. He is the author of the popular book *Trees* for the Natural History Museum. Recently he has broadened his work on trees, collaborating with planners within the university, with the Red Rose Forest and Barcham Trees to study the environmental benefits of trees and grassland in urban areas, and their role in climate-proofing our cities. This has included both modelling studies, and more recently experimental investigations into the effectiveness of trees in providing shade and cooling and in preventing local flooding.

## Neville Fay (Session Chair)

**Director, Treework Environmental Practice, UK**

Neville is the founder of Treework Environmental Practice, a leading UK multi-disciplinary consultancy. He is a Chartered Arboriculturist and chairs the Ancient Tree Forum and the National Tree Safety Group drafting subcommittee. He is an expert witness in tree-related personal injury and environmental cases with 25 years of experience in tree planning, habitat and public safety consultancy. Neville was a founder of the charity Tree Aid and developed the 'Innovations in Arboriculture' seminars to advance UK arboricultural knowledge. In 2009, he received the Arboricultural Association Award for services to arboriculture. Neville lectures in the UK, USA and Europe and has co-authored the *Specialist Survey Method, Veteran Trees: A guide to Risk and Responsibility* and *Tree Surveys: a guide to good practice*.

## Dr Francesco Ferrini (Speaker)

**Professor of Arboriculture, Department of Plant, Soil and Environmental Science, University of Florence, Italy**

Francesco is President of the Italian Chapter of the International Society of Arboriculture (ISA). His scientific activity is mainly addressed at research and experimental studies regarding ornamental and urban arboriculture. Since 1990, he has published more than 170 scientific and technical papers in Italian (85) and in English (89) in international referred and nationwide journals. He has given more than 90 talks in several international and national congresses. In 2010, he was the recipient of the ISA's L.C. Chadwick Award for Arboricultural Research, awarded to individuals to recognise research that has contributed valuable information to the practice of arboriculture.

## Kathryn Gilchrist (Speaker)

**School of the Built Environment, Heriot-Watt University, UK**

Kathryn graduated with a BSc in Ecological Science from Edinburgh University in 2006, and gained her MSc in Urban and Regional Planning from Heriot-Watt University in 2009. She is currently studying for a PhD in Environmental Planning at Heriot-Watt. Her research focuses on restorative environments, and in particular the perceptions and use of open space in urban-fringe business developments. In 2010, Kathryn was honoured by the Royal Town Planning Institute (RTPI) with an award for 'Outstanding Student Achievement in Planning Education' at the RTPI Planning Awards in London.

## Peter Head, OBE (Speaker)

**Consultant to Arup, UK**

Peter is a civil and structural engineer who has become a recognised world leader in major bridges (receiving the OBE), advanced composite technology and now in sustainable development in cities. He has won many awards for his work including the Award of Merit of IABSE, the Royal Academy of Engineering's Silver Medal and the Prince Philip Award for Polymers in the Service of Mankind. He joined Arup in 2004 to create and lead their planning and integrated urbanism team which has now doubled in size. He was appointed in 2002 by the Mayor of London as an independent Commissioner on the London Sustainable Development Commission. He is an expert adviser to the Singapore Government on Green Buildings and Infrastructure and he is on the advisory panel for the World Future Council. In July 2008, he received an honorary doctorate at Bristol University where he is a visiting Professor. In 2009, he was awarded the Sir Frank Whittle medal of the Royal Academy of Engineering for a lifetime contribution to the wellbeing of the nation through environmental innovation. He was cited by *Time* magazine in 2008 as one of 30 global eco-heroes and has been one of CNN's Principle Voices.

## Andrew Hirons (Speaker)

**Lecturer in Arboriculture, Myerscough College, UK**

Andrew graduated from Myerscough College with BSc (Hons) Arboriculture in 2003. After pursuing an opportunity to work as a climber and plant health care technician in the USA, Andy returned to England and joined the Arboriculture Department at Myerscough College, Lancashire. His principal teaching responsibilities and academic interests are in tree physiology. Consequently, Andy has a keen interest in integrating fundamental science into arboricultural practice and, in particular, the challenges of establishing trees in the urban landscape. He is currently working on a PhD which aims to provide a more sustainable model for water use in amenity tree nurseries by presenting alternative irrigation approaches and exploiting tree physiological responses to moderate water deficits.

## Dr Mark Johnston, MBE (Conference Chair and Speaker)

**Research Fellow in Arboriculture and Urban Forestry, Myerscough College, UK**

Mark is Myerscough College's Course Leader for its MSc Arboriculture and Urban Forestry, where he also researches the social science aspects of urban tree management. He is a Fellow of the Institute of Chartered Foresters, a Chartered Arboriculturist, Fellow of the Institute of Horticulture, Member of the International Society of Arboriculture, and has 40 years' experience in the public, private and voluntary sectors. He has initiated several major urban forestry projects in Britain and Ireland and has extensive international experience. He recently acted as the lead researcher and main author of the government's *Trees in Towns II* report on the condition and management of urban trees in England. In 2007, Mark was appointed MBE in recognition of his services to trees and the urban environment. In 2009, he became the first British person to receive the Award of Merit from the International Society of Arboriculture, the highest honour it can bestow for services to arboriculture and urban forestry.

## Martin Kelly (Speaker)

**Managing Director, Capita Lovejoy, UK**

Martin is a qualified Landscape Architect and Urban Designer and is a Fellow of the Landscape Institute, Fellow of the Institute of Highways and Transportation and Fellow of the Royal Society of Arts. Following three years in the public sector, Martin joined Derek Lovejoy Partnership (now Capita Symonds) in 1979, where he became a Partner in 1986 and Managing Director in 1996. During this time, he has specialised in environmental land planning for major landmark projects on behalf of public and private sector promoters in the UK and overseas. Martin is also a CABE Space Enabler as well as Chairman and Founder of the Trees and Design Action group (TDAG) and Vice Chairman of the Victoria Business Improvement District.

## Dr Val Kirby (Session Chair)

**Principal Specialist, Professions and Communities, Natural England, UK**

Val is a landscape architect and town planner and has a research degree in cultural geography. In her present post she champions landscape, geodiversity and the historic environment within Natural England and to external partners and stakeholders. She leads on developing strategic thinking and linking that to ways of working, so that an integrated view of landscape is taken across Natural England and beyond. For 12 years she worked in New Zealand, teaching landscape architecture and doing research into contests between cultural and natural heritage. Before that she worked in a number of local authority posts in England, including six years with the Yorkshire Dales National Park.

# Guest Speaker for Conference Dinner

## Tony Kirkham

**Head of the Arboretum and Horticultural Services, Royal Botanic Gardens, Kew, UK**

Following an apprenticeship in forestry and two years as an arborist, in 1978 Tony started at the RBG Kew on the Diploma course, graduating in 1982. In 2001 he became the Head of the Arboretum and Horticultural Services, responsible for the management and curation of the tree collections. He has participated in and led several plant collecting expeditions to Chile and the Far East of Asia, including China, Taiwan, Japan, South Korea and Russia. In 2004 he completed the revision of George Brown's *Pruning of Trees Shrubs and Conifers*. Tony featured in the BBC2 series 'A Year at Kew' and in September 2006 presented the 'Trees that made Britain' series for BBC2. He represents Kew on the Castle Howard Arboretum Trust and International Dendrology Society, and is a trustee of The Tree Register. In 2009 Tony was awarded the Associate of Honour by the RHS for distinguished service to horticulture.

## Dr Cecil C. Konijnendijk (Speaker)

**Professor of Green Space Management, Danish Centre for Forest, Landcape and Planning, University of Copenhagen, Denmark**

Cecil coordinates the Centre's research group on Parks, People and Policies. He holds an MSc in forest policy from the University of Wageningen, Netherlands, and a DSc in forest policy and economics from the University of Joensuu, Finland. Cecil has studied and promoted the role of forests, trees and green spaces in urban societies across the world. He has a special interest in urban forestry, green space strategies and policies, functions of green space, as well as communication, marketing and public involvement issues. Cecil has authored about 200 publications and is editor-in-chief of the scientific journal *Urban Forestry and Urban Greening*.

## Dr Anna Lawrence (Speaker)

**Head of the Social and Economic Research Group, Forest Research, UK**

Anna combines a background in botany (BA in Natural Sciences, University of Cambridge) and forestry (MSc in Forestry and its relation to land use, University of Oxford) with social science (PhD, University of Reading: 'Tree-cultivation in upland livelihoods in the Philippines: implications for biodiversity conservation and forest policy'). She has 20 years of experience in social forestry, and research into the cultural, social and political aspects of environmental management, in 23 countries. She developed the Human Ecology Programme at Oxford University's Environmental Change Institute during 2001–2007. In January 2008, she joined the Forestry Commission (Forest Research), where she is responsible for a programme of research into social benefits of trees, woods and forests, and community and policy engagement. Anna is a Visiting Professor in the Forest and Nature Conservation Policy Group, University of Wageningen, the Netherlands.

## John A. Lockhart (Session Chair)

**Chairman, Lockhart Garratt Ltd, UK**

John co-founded Lockhart Garratt Ltd in 1998, since when it has become a leading tree, woodland and forestry consultancy based in the East Midlands. He is a Fellow of the Royal Institution of Chartered Surveyors (RICS) and has been a Member of the RICS Rural Professional Group since 2000, co-opted to provide tree, woodland and forestry expertise. He is the RICS representative on the Forestry Commission's England Applicants Focus Group and a member of its Valuation Steering Group, assisting in the development of the new RICS guidance note on the *Valuation of Woodland* (1st edition 2010). John is also a Chartered Environmentalist and Member of the Management Committee of the National Tree Safety Group.

## Dr Rob MacKenzie

**Reader in Atmospheric Science, Lancaster Environment Centre, Lancaster University, UK**

Rob has been at Lancaster since 1998. Prior to that Rob worked in the Chemistry Department of Cambridge University as a Senior Research Associate and Coordinator of the university's Centre for Atmospheric Sciences. His first degree was in Environmental Chemistry, from Edinburgh University, and his PhD was on 'Small System Modelling of the Atmospheric Boundary Layer', at the University of Essex. Rob's PhD work included the first UK study of the impact of emissions of volatile organic compounds from trees on air quality. He has a continuing interest in understanding the role of trees and urban green space on air quality, producing, for instance, the Urban Tree Air Quality Score for use by urban design practitioners.

## Margaret MacQueen (Speaker)

**Consultant Arboriculturist, Expert and Legal Services, OCA UK Limited, UK**

Margaret first qualified in 1977 and worked within the private sector managing both forestry and amenity trees for 12 years. Employment in local government followed in 1990 in the Conservation Department of a District Council for 14 years. During this time Margaret dealt with all statutory tree applications and landscape planning issues, formulating policies for tree retention and management. She managed all the council-owned amenity trees and areas of woodland as well as training voluntary groups such as the Parish Tree Wardens. Margaret joined OCA UK Limited in 2004 and since 2006 has been employed as Lead Consultant within its Expert, Legal and Consultancy Team and has overall responsibility for audit and training for all matters relating to statutory procedures and subsidence. She is also a member of the Landscape Planning Limited review group responsible for consultation and comment on changes to legislation and developments affecting trees and landscape. Margaret is a Chartered Arboriculturist and Member of the Academy of Experts.

## Dr Sylvie Nail (Speaker)

**Professor of British Studies, University of Nantes, France**

Sylvie teaches contemporary British Studies at the Centre International des Langues in the University of Nantes. Her research focuses on the intersection of culture and policy in its relationship to the environment in England. She is the author of numerous articles dealing with private gardens, urban parks and forests and the author of the book *Forest Policies and Social Change in England* (Springer, 2008), as well as the editor of a book on *Urban Forests in Latin America: Uses, Functions, Representations* (Universidad Externado de Bogota, 2006) and co-editor of a book on New Labour's 'Urban Renaissance' (*Vers une Renaissance urbaine? Dix and de politique travailliste de la ville*, Presses de la Sorbonne Nouvelle, 2009).

## Dr Dealga O'Callaghan (Speaker)

**Tree and Vegetation Manager, Western Power Distribution, Midlands, UK**

Dealga is an Alumnus of University College Dublin. He is a Chartered Arboriculturist, a Fellow of the Arboricultural Association, an Adjunct Full Professor in the School of Forest Resources at Clemson University, South Carolina, and an examiner for the Professional Diploma in Arboriculture. He has worked in both education and private sector consulting for many years and has published papers in peer-reviewed journals on many aspects of arboriculture. He is an accredited Expert Witness and has acted in many cases in the English, Manx and Irish Courts. He is a founder member and was the first President of the UK&I Chapter of the International Society of Arboriculture (ISA), and he was the General Conference Chair for the ISA's 74th Annual Conference held in Birmingham, England, in 1998.

## Dr Glynn Percival (Speaker)

**Senior Plant Physiologist, R.A. Bartlett Tree Expert Company Ltd, UK**

Glynn manages Bartlett's research and diagnostic laboratory at the University of Reading. He is a professional member of the International Society of Arboriculture and Arboricultural Association. Glynn has presented papers on his work at the International Society of Arboriculture and Arboricultural Association annual conferences and at the International Society for Horticultural Science, 1st International Symposium on Urban Tree Health. He is the author of over 100 scientific papers, magazine articles and book chapters. Glynn is on the editorial board for *Arboriculture and Urban Forestry* and *Urban Forestry and Urban Greening* and is an honorary lecturer at Reading University.

## Ian Phillips (Session Chair)

**Independent Landscape Consultant, UK**

Prior to establishing as a consultant, Ian managed planning policy, landscape and conservation services at Hart Council in Fleet, Hampshire. Previously he worked with London-based architects FRHJ on commercial landscape designs and with the London Borough of Camden on trees and landscape in planning. Since establishing as an independent consultant, Ian has worked on a wide variety of projects for clients in the public, private and 'not for profit' sectors and has particular interests in community engagement and green infrastructure. He has worked as an Enabler with CABE Space in these areas and helped develop the Spaceshaper community consultation tool. He has been a member of several committees of the Landscape Institute and represented the Institute on various tree-related British Standards committees. Ian is a Director and Trustee of the Tree Advice Trust.

## Stephen Plante (Speaker)

**Director, The Clay Research Group, UK**

Stephen has been engaged as a consultant advising insurers and their agents for over 20 years. In that time he has developed software to gather data on domestic subsidence claims which includes information about trees and soils. This was the starting point for his current research programme. In 2006 he formed the Clay Research Group to investigate moisture change beneath mature trees on fine-gained soils in relation to climate at a research site in North London. Several academics were invited to join the project and the site has delivered valuable information using a variety of techniques. He has developed several risk models for insurers and is currently researching methods that may allow the retention of trees that are causing damage to houses.

## Katie Roberts (Speaker)

**Projects Director, Trees for Cities, UK**

Katie directs all aspects of Trees for Cities' community and arboriculture project work, from consultation and landscape design to public tree planting celebration events in London and across the UK. Since 2005, she has been working as part of the charity's Community and Education Team using her broad experience of environmental projects to engage London's diverse population in the restoration and transformation of neglected green areas, streets and urban parks into valued community gardens, orchards and woodlands. Accredited with a BSc (Hons) in Environmental Science from Southampton University and an MSc (Hons) in Applied International and Rural Development at the University of Reading, her range of environmental community projects outside Trees for Cities have included securing community development and conservation through ecotourism in Kenya, a community managed National Park in Belize and environmental education programmes in Trinidad and Malawi.

## Kenton Rogers (Speaker)

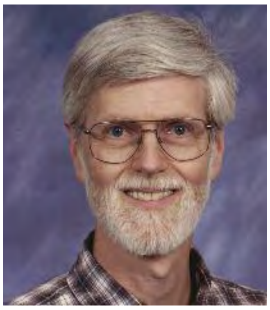
**Senior Consultant, Hi-line Consultancy, UK**

Kenton is an arboricultural and woodland consultant based in South West England who has worked in the disciplines of arboriculture and silviculture for around 20 years. Starting out as a Field Technician with Forest Research, prior to study at Newton Rigg, he later set up and directed a successful land management company. Kenton has since worked on tree projects in Cyprus, Canada and Africa. He is a Fellow of the Royal Geographical Society and has been a serving trustee on the board of the International Tree Foundation for five years, where he helped develop and extend its drylands programme in the Sahara and Sahel. Currently, Kenton is currently undertaking a Masters Degree in Forest Ecosystem Management at the National School of Forestry.

## Keith Sacre (Session Chair)

**Sales Director, Barcham Trees plc, UK**

Keith has over 20 years of experience in local government as nursery, parks and operations manager. He then spent 11 years with Notcutt's Nurseries with responsibility for tree sales to local authorities and other trade outlets. He now works as Sales Director with Barcham Trees, the largest container tree nursery in Europe. Keith is a member of the Institute of Chartered Foresters and a Chartered Arboriculturist. Has a BSc in Social Science and BSc (Hons) in Arboriculture from Myerscough College. He is currently studying part-time for an MSc in Arboriculture and Urban Forestry at Myerscough College.



## Dr Herbert W. Schroeder (Speaker, but was unable to attend in person)

**Research Social Scientist, United States Department of Agriculture, Forest Service, USA**

Herb Schroeder works for the USDA Forest Service in Evanston, Illinois, in a research unit that studies the social aspects of natural resource management with particular emphasis on urban populations. Dr Schroeder's research has addressed diverse aspects of how people experience and value trees and forest environments. He has done research on public preferences and perceptions of aesthetic value, safety and recreation quality in forest, park and residential environments. He has studied homeowners' perceptions of the benefits and annoyances of street trees; the meanings, values and experiences that people associate with special outdoor places; and the deeper symbolic and spiritual values of trees and forests.

## Eyob Tenkir Shikur (Speaker, but was unable to attend in person)

**Addis Ababa Environmental Protection Agency, Ethiopia**

Eyob was born in Addis Ababa in 1974. In his current post he is a researcher on urban ecosystems and biodiversity. His academic credentials include a BSc in General Forestry from Alemaya Agricultural University, Ethiopia, and an MSc in Botanical Science from Addis Ababa University, Ethiopia. He has worked as lead expert on the green environment for a consultancy firm and is a Founder and Member of the Indigenous Tree Development and Environmental Conservation Organization. Eyob has more than 14 years of experience on forest inventories, urban forest protection and plant taxonomy. He also focuses on raising awareness of urban forest ecosystem rehabilitation and urban biodiversity. He has been published widely in different scientific publications in the forestry field. He is currently establishing a 20 ha medicinal and ornamental plant garden for use as a research plot.

## Jim Smith (Session Chair)

**Project Development Manager, London Region, Forestry Commission, UK**

Jim has been an arboriculturist for over 25 years. He first worked for the Forestry Commission on leaving school and returned to London to work as an arborist in the Royal Parks in the early 1980s. He then worked as a tree contractor in North London before becoming a tree officer, working in a number of local authorities in London. He has twice been Chair of the London Tree Officers Association and has been involved in the production of many national and regional guidance documents involving trees. He was appointed the London Tree and Woodland Framework Manager in 2006 and works in the Forestry Commission's London Region Office and is also Forestry Commission England's principal advisor on arboriculture.

## Mike Townsend, OBE (Speaker)

**Senior Advisor for Specialist Communications and Evidence, The Woodland Trust, UK**

Mike has a first degree in forestry and a Masters Degree in Environmental Policy and Society, and is a Fellow of the Institute of Chartered Foresters. His career includes periods in community forestry in Kenya, work in the commercial forestry sector in the UK and 15 years at the Woodland Trust, including as Operations Director and Chief Executive. Current areas of interest include the role of trees in urban adaptation to climate change, and integration of trees and forestry into farming systems. He was appointed OBE in 2001 for services to the forest industry.

## Pam Warhurst, CBE (Speaker)

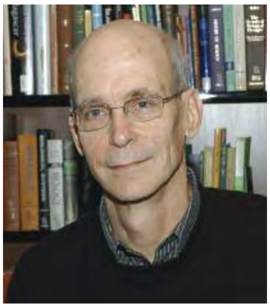
**Chair, Forestry Commission, UK**

Pam originally trained as an economist. She was Chair of a food co-operative for 20 years, and ran a vegetarian café for 10 years before passing it on to her daughter. Prior to being appointed as Chair of the Forestry Commission in January 2010, Pam held a number of relevant public appointments, including Board Member of Natural England, Deputy Chair of the Countryside Agency, Chair of the National Countryside Access Forum, and Chair of the Calderdale NHS Trust. She still serves as a Member of Tourism Body Yorkshire and Humberside, Chair of Pennine Prospects in South Pennines, and Chair of the Community Station Partnership, Todmorden. Pam is a Fellow of Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA) and was appointed CBE in 2005 for services to the environment.

## Philip van Wassenaer (Speaker)

**Principal Consultant, Urban Forest Innovations Inc., Canada**

Philip is principal consulting arborist and founder of Urban Forest Innovations Inc. He has over 20 years' experience as a practicing arborist, has been a Certified Arborist of the International Society of Arboriculture (ISA) since 1996 and has been a member of the American Society of Consulting Arborists since 1999. Philip served as both President and Director of the Ontario Urban Forest Council and his academic qualifications include an undergraduate degree in Environmental Sciences and a Masters Degree in Forest Conservation, from the University of Toronto. In 2009 Philip was a recipient of the ISA 'True Professionals of Arboriculture' award in recognition of his commitment to education and the advancement of arboriculture.



## Dr Gary W. Watson (Speaker)

**Head of Research, The Morton Arboretum, Illinois, USA**

Gary joined the Morton Arboretum in 1986 and worked as Senior Scientist before rising to his current position in 2009. His primary research interest is in understanding how to maintain a healthy balance between the crown and the root system of trees on difficult landscape sites. Gary has received the L.C. Chadwick Award for Arboricultural Research and Richard W. Harris Author's Citation Award from the International Society of Arboriculture (ISA). He is a Past President of the ISA, the Arboricultural Research and Education Academy and the Illinois Arborist Association. Gary is also Editor-in-Chief of *Arboriculture and Urban Forestry*, organiser of 'The Landscape Below Ground' Conferences and Editor of that conference's proceedings.

## Matthew Wells (Speaker)

**Director of Tree Preservation, NYC Department of Parks and Recreation, New York, USA**

In his current post Matthew's main duties include overseeing the Trees and Sidewalks Program as well as enforcing and developing new policies for protecting the estimated 2.6 million public trees of New York City. He started his career 15 years ago and since then has worked in urban forestry in both the private and public sectors of the UK and the USA. Before moving across the Atlantic from his native England, he spent many years as a Tree Officer in central London. He has been in New York City for nearly eight years, of which six have been with the Forestry Division of the Parks Department.

## Adam Winson (Speaker)

**Consulting Arboriculturist, JCA Ltd, UK**

Adam initially worked as a tree surgeon, where he enjoyed climbing trees throughout Europe and Australia. He returned home to study a BSc (Hons) in Environmental Conservation at Sheffield Hallam University and began working as a Consulting Arboriculturist. Adam recently obtained an MSc in Arboriculture and Urban Forestry (with distinction) from Myerscough College, where he also gained the Top Student Award. His research interests include how the urban forest is perceived and how it may benefit human health and wellbeing.

# Appendix 3: Poster exhibition

The following poster presentations were displayed in the main exhibition area of the conference. The opportunity to present a poster was offered to all authors whose submissions were not included in the main conference programme. Space was limited to 20 posters and these were allocated on a 'first come, first served' basis. Two authors who were given the opportunity to present a poster then withdrew at the last moment and it was too late to replace one of these. The overall quality of the poster presentations was very high and the exhibition attracted much favourable comment from the delegates.

## P-01

**Title:** Advances in non-destructive geophysical methods for trunk and root system imaging
**Author/s:** Steffen Rust, Dirk Bieker, Rolf Kehr, Andreas Koch, Mitja Vianden, Falko Kuhnke, Ulrich Weihs – University of Applied Sciences and Arts, Büsgenweg, Göttingen, Germany
**Contact:** rust@hawk-hhg.de

## P-02

**Title:** An assessment of urban forestry in Pokhara sub-metropolitan city Kaski district, Nepal
**Author/s:** Jyoti Bhandari – Institute of Forestry, Tribhuvan University, Pokhara, Nepal
**Contact:** angeljb7@yahoo.com

## P-03

**Title:** A study of tree spacing on canopy development
**Author/s:** Mark Duntemann – Natural Path Urban Forestry Consultants, Chicago, USA
**Contact:** natpath@earthlink.net

## P-04

**Title:** Trees and daylight
**Author/s:** Rodney Helliwell – Independent Arboricultural Consultant, UK
**Contact:** mail@rodneyhelliwell.com

## P-05

**Title:** Effect of trees and surface type on temperature, thermal comfort and rainfall runoff in cities
**Author/s:** David Armson, Roland Ennos – Faculty of Life Sciences, University of Manchester, UK
**Contact:** David.Armson@postgrad.manchester.ac.uk

## P-06

**Title:** Analysis of morphological and phenotypical diversity of *Discula platani*, causal agent of plane tree anthracnose
**Author/s:** Maria-Luisa Tello – Plant Pathology Lab, IMIDRA (Madrid Institute for Agricultural Research and Rural Development), Spain
**Contact:** marisa.tello@madrid.org

## P-07

**Title:** Ethnic diversity and use of urban green space – case studies of Kuala Lumpur and Kuching, Malaysia
**Author/s:** A.A. Nor Akmar, C.C. Konijnendijk, K. Nilsson – Centre for Forest, Landscape and Planning, University of Copenhagen, Denmark
**Contact:** naaa@life.ku.dk

## P-08

**Title:** Gardens in acute-care hospitals – A study in Copenhagen, Denmark
**Author/s:** Shureen Faris, Abdul Shukor – Forest and Landscape, University of Copenhagen, Denmark
**Contact:** sfar@life.ku.dk

## P-09

**Title:** Concentrations and ratios of chemical elements in common lime leaves in the street greenery of Riga (Latvia)

**Author/s:** Gunta Cekstere, Anita Osvalde – Laboratory of Plant Mineral Nutrition, Institute of Biology, University of Latvia, Latvia

**Contact:** guntac@inbox.lv

## P-10

**Title:** Applicability of the Norma Granada method to evaluate adult trees – a case study

**Author/s:** Romaine van Krimpen – Landscape Architecture Master Student at Évora University, Teresa Cordeiro Féria – Landscape Architect, Municipality of Évora and Maria da Conceição Castro – Landscape Architect, Teacher at Évora University, Portugal

**Contact:** mccastro@uevora.pt

## P-11

**Title:** Current status and future potential of public involvement in Danish municipal urban green space maintenance

**Author/s:** Julie Frøik Molin, Cecil C. Konijnendijk – Forest and Landscape, University of Copenhagen, Demark

**Contact:** molin@life.ku.dk

## P-12

**Title:** Effect of growth conditions on the performance and cooling ability of street trees

**Author/s:** M.A. Rahman, A.R. Ennos – Faculty of Life Sciences, University of Manchester, UK

**Contact:** Mohammad.Rahman-3@postgrad.manchester.ac.uk

## P-13

**Title:** The electronic nose as diagnostic instrument for the detection of decay in the urban trees

**Author/s:** G. Villa, L. Bonanomi, L. Pozzi, D. Guarino – Coop Demetra, Besana Brianza, Milan, Italy

**Contact:** mauri@demetra.net

## P-14

**Title:** The (sad) history of the Giant of Campagnola

**Author/s:** Pierre Raimbault – Private consultant, Giovanni Morelli – Studio Progetto Verde, Ferrara, and Stefania Gasperini – AR.ES. sas, Ferrara, Italy

**Contact:** stefaniagasperini@arbestense.it

## P-15

**Title:** The effects of novel water management techniques on ornamental tree (*Betula pendula* Roth.) production

**Author/s:** A.D. Hirons – Myerscough College, UK, W.J. Davies – Lancashire University, UK, E.D. Elphinstone – Myerscough College, UK

**Contact:** ahirons@myerscough.ac.uk

## P-16

**Title:** Oak tree structural joint breakage

**Author/s:** Eve Walkden – University of Southampton, School of Civil Engineering and the Environment, UK

**Contact:** E.Walkden@soton.ac.uk

## P-17

**Title:** The roles of trees and urban forest in the Tivoli, Rožnik, and Šiška Hill Landscape Park in Ljubljana

**Author/s:** Mateja Šmid Hribar, Bojan Erharti, Aleš Smrekar – Anton Melik Geographical Institute of Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Slovenia

**Contact:** mateja.smid@zrc-sazu.si

## P-18

**Title:** The valuation of trees for amenity and related non-timber uses

**Author/s:** Charles Cowap – Royal Institution of Chartered Surveyors, UK

**Contact:** 00010070@harper-adams.ac.uk

## P-19

**Title:** Carbon sequestration of urban trees in Hamburg: a methodological approach

**Author/s:** Stefanie Poepken, Susanne Lost, Michael Koehl – Johann Heinrich von Thuenen Institute, Institute for World Forestry, Hamburg, Germany

**Contact:** stefanie.poepken@vti.bund.de

# Appendix 4: Delegates list for Trees, people and the built environment – 13 and 14 April 2011

**Bold**: **Speakers/Chairs**; **Overseas**: Country shown in italics
W: Wednesday only or T: Thursday only delegate

| Delegate name | Organisation |
|---|---|
| Abbatt, Ben | Sapling Arboriculture Ltd |
| Abbott, Stan | Forestry Commission England SEEFD |
| Abdul Aziz, Nor Akmar | University of Copenhagen, ***Denmark*** |
| Abdul Shukor, Shureen Faris | University of Copenhagen, ***Denmark*** (T) |
| Adams, Lesley | Symbiosis Consulting Ltd |
| Appleyard, Hal | ACS Consulting (W) |
| Armson, David | University of Manchester |
| Ashman, Mark | Hill-fort Tree Care & Consultancy |
| Ashton, Maxine | Myerscough College |
| **Askew, Janet** | **University of the West of England** (T) |
| Baines, Chris | Baines Environmental Ltd |
| Baker, Ruth | Derbyshire County Council |
| Ball, Russell | ArbolEuro Consulting |
| Bardey, James | Myerscough College |
| Barkel, Curtis | Independent |
| Barrow, Ian | Bartlett Tree Experts |
| Barton, Nicholas | Amey LG Ltd |
| Barton, Paul | Acorn Environmental Management Group |
| Beadle, David | Derby City Council (T) |
| Benson, Warren | Acorn Environmental Management Group (T) |
| Birchall, Caroline | Natural England |
| Blake, Dominic | Advanced Tree Services Ltd |
| Blunnie, Eimear | Oxford Brookes University |
| **Body, Stuart** | **Flintshire County Council** |
| Bogdanou, Thalia | Institute of Chartered Foresters |
| Bolton, Julie | West Sussex County Council |
| Bowie, Dean | Greenleaf |
| Braddock, Ian | ADAS |
| **Brady, Angela** | **Royal Institute of British Architects** (T) |
| Bray, Jamie | Treetop Arboriculture |
| Brewer, Jane | Bath & North East Somerset Council |
| Broome, Gareth | Nottinghamshire County Council |
| Brown, Michelle | Flintshire County Council |
| Brown, Nathan | Imperial College (W) |
| Brown, Tim | Bartlett Tree Experts (T) |
| Brunt, Andy | Forest Research (W) |
| Buckley, Martin | South Derbyshire District Council (T) |
| Burgess, Keith | Amey LG Ltd |
| Burton, James | Royal Borough of Kensington & Chelsea |
| Caldicott, Kevin | Oxford City Council |
| Callis, Jonathan | Network Rail |
| Carroll, Michael | Countryside Commission (W) |
| Carter, Mark | Broadlands Estate |

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|---|---|
| Carvey, Ellen | Barcham Trees plc |
| Casey, Paul | Harrogate Borough Council (W) |
| Cekstere, Gunta | University of Latvia, ***Republic of Latvia*** |
| Challice, David | Challice Consulting (W) |
| Chamberlain, Rachel | Forestry Commission Wales |
| Chambers, Chris | Myerscough College (W) |
| Chambers, Shireen | Institute of Chartered Foresters |
| Choi, Lim Cho Kingsley | Leisure and Cultural Services Department, ***Hong Kong SAR*** |
| Clary, Bryan | Lockhart Garratt Ltd |
| Clewlow, Leigh | Leicestershire County Council |
| Clout, Andy | Waverley Borough Council |
| Coakes, Matthew | Askham Bryan College |
| Cocking, Jonathan | JCA Ltd, Arboricultural Consultants (W) |
| Colebrook, Andrew | ACAC |
| Coles, Richard | Birmingham City University (W) |
| Collins, Kevin | The Society of Irish Foresters, ***Republic of Ireland*** |
| Collis, Paul | Paul Collis & Associates |
| Coltard, Kevin | Homegrown Timber Rail Ltd (W) |
| Coombes, Andrew | A T Coombes Associates |
| Coppock, Roger | Forestry Commission |
| Counsell, John | UWIC |
| Cox, David | RPS Group |
| Cox, Steve | Treecall Consulting Ltd |
| Crane, Brian | Brian G Crane & Associates |
| Crowther, Jane | Royal Borough of Windsor and Maidenhead |
| Cullen, Arthur | West Berkshire Council (W) |
| Curling, Neil | Lloyds Banking Group General Insurance (T) |
| Dale, Ian | Cheshire East Council |
| Dalrymple, James | Greenleaf |
| **Dandy, Dr Norman** | **Forest Research** |
| Dantas, Innes | University College of London |
| Davidson, Bruce | East Ayrshire Woodlands |
| Davidson, Rob | ADAS |
| Davies, Clive | Food and Agriculture Organisation of the United Nations |
| Davies, Richard | Forestry Commission Wales (W) |
| **Denman, Dr Liz** | **University of Melbourne, *Australia*** |
| Dobson, Rosie | Westminster City Council (T) |
| Dobson, Shona | Groundwork North East |
| Doornenbal, Dirk | Nationale Bomenbank BV, ***Netherlands*** |
| Driver, Dominic | Forestry Commission England |
| Dudding, Mike | Askham Bryan College |
| Dudley, Ian | Lockhart Garratt Ltd |
| Dudley, Lee | The Woodland Trust |
| Durguti, Shqipe | InterSilva, ***Kosovo*** |
| Durk, Mark | Forestry Commission |
| Dyson, Ed | Defra |
| Eaton, Edward | Independent (W) |
| Eden, Nick | Arboricultural Association |
| Edmonds, Ruth | Myerscough College |
| Elg, Roger | Swedish University of Agricultural Sciences, ***Sweden*** |
| **Ennos, Dr Roland** | **University of Manchester** |
| Evans, Prof. Julian | Independent |

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|---|---|
| Farrow, Paul | Birmingham Trees for Life |
| Fawcett, Pamela | Places for Landscapes Ltd |
| **Fay, Neville** | **Treework Environmental Practice** |
| **Ferrini, Dr Francesco** | **University of Florence, *Italy*** |
| Francis, Neil | Askham Bryan College |
| Freed, Cliff | Acacia Tree Surgery Ltd |
| Frøik Molin, Julie | University of Copenhagen, ***Denmark*** |
| Frost, Bob | Forestry Commission Scotland |
| Fryer, Dafydd | Forestry Commission Wales |
| Fung, Ming | Reading University |
| Gammie, Martin | Consulting with Trees Ltd |
| Garside, Stewart | East Hampshire District Council |
| Gasperini, Stefania | AR.ES. Sas, ***Italy*** |
| Gazzard, Rob | Forestry Commission England SEEFD |
| Gershon, Simon | Lancaster Green Spaces |
| **Gilchrist, Kathryn** | **Heriot-Watt University** |
| Gilpin, John | Sheffield City Council |
| Glassey, Peter | Burghley House Preservation Trust |
| Glover, Nina | University College of London |
| Good, Russell | Birmingham City University |
| Goodall, Adam | Sheffield City Council |
| Goodwin, Duncan | Capita Symonds |
| Gorner, Glen | Leeds City Council |
| Gosling, Adam | Acorn Environmental Management Group (W) |
| Greenaway, Ben | The Mersey Forest (W) |
| Griffith, Sue | Birmingham Trees for Life |
| de Groot, Jan-Willem | Boomadviesbureau De Groot BV, ***Netherlands*** |
| Hare, Gareth | Lichfield District Council |
| Harris, Phillip | Bowland Tree Consultancy Ltd |
| Hayden, Dorothy | Teagasc, ***Republic of Ireland*** (W) |
| Hayden, Nicholas | East Dorset District Council |
| Hayden, Stephen | Haydens Arboricultural Consultants |
| **Head, Peter** | **Arup** (T) |
| Hearn, Alistair | Treescapes Consultancy Ltd |
| Helliwell, Rodney | Independent |
| Hemery, Gabriel | Sylva Foundation (W) |
| Herridge, Gary | Bartlett Tree Experts (W) |
| Hesch, Becky | London Tree Officers Associationv |
| Heslegrave, Bill | Forestry Commission |
| Heuch, Jon | Duramen Consulting Ltd |
| Hewitt, Anthony | Parkwood Holdings plc (W) |
| Hibbert, Stuart | Stockton on Tees Borough Council (W) |
| Hill, Emma | Trees for Cities (W) |
| Hill, Gary | Bartlett Tree Experts (W) |
| **Hirons, Andrew** | **Myerscough College** |
| Hislop, Max | Glasgow and Clyde Valley Green Network Partnership |
| Hobbs, Alex | Independent |
| Holland, Owain | Myerscough College |
| Holman, Tim | Eastleigh Borough Council |
| Holmes, Simon | Tree Surveys |
| Hommel, Matt | Christie Elite Nurseries |
| Hopkins, Edmund | Nottingham City Council |

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|---|---|
| Horsey, Russell | Bristol City Council |
| Horton, Colin | North Lincolnshire Council |
| Hosegood, Sharon | DF Clark Bionomique Ltd |
| Howe, Portia | Lichfield District Council |
| Hudson, Christopher | Cheshire East Council |
| Hudson, Mark | Independent |
| Humphreys, Jason | Derby City Council (T) |
| Hunter, John | Stairway Trees (W) |
| Hutchings, Tony | Forest Research (W) |
| Hyett, Richard | Swindon Borough Council |
| Ibrahimi, Rema | InterSilva, ***Kosovo*** |
| Ince, Richard | InterSilva, ***Kosovo*** |
| Ingram, Chris | Quaife Woodlands |
| Jackson, Jonathan | Greenmount College, Northern Ireland (T) |
| James, Sue | Trees and Design Action Group |
| Jansson, Malin | J & L Gibbons (T) |
| Jenner, Anthony | The Parks Trust |
| Jennings, Emma | Wardell Armstrong (W) |
| Johnson, David | Barcham Trees plc |
| **Johnston, Dr Mark** | **Myerscough College** |
| Johnston, Sarah | Independent (T) |
| Jones, Keith | Forestry Commission |
| Jones, Laura | Forestry Commission England |
| Jones, Nerys | Independent |
| Joye, Tom | Inverde, ***Belgium*** |
| Karl, Lee | West Coast Network Services Ltd |
| Keighley, Jennie | University of Cumbria, Newton Rigg |
| **Kelly, Martin** | **Capita Symonds** (T) |
| Kerr, Gary | Forestry Commission |
| Kidd, Stuart | North Kesteven District Council |
| **Kirby, Val** | **Natural England** |
| Kirk, Helen | FPCR Environment & Design Ltd |
| **Kirkham, Tony** | **Royal Botanic Gardens, Kew** |
| **Konijnendijk, Dr Cecil** | **University of Copenhagen, *Denmark*** |
| Kryeziu, Sami | InterSilva, ***Kosovo*** |
| Lane, Tony | A M Lane Ltd |
| Langhorn, Neil | Forestry Commission Scotland |
| Lanigan, Shane | Urban Forestry |
| **Lawrence, Dr Anna** | **Forest Research** |
| Lawson, Michael | Landscape Planning Group Ltd (W) |
| Leslie, Roderick | Independent |
| Lewis, Dylan | Moulton College |
| Lewis-Farley, Chris | Malvern Hills District Council |
| Linford, Ken | Tree Check Ltd |
| **Lockhart, John** | **Lockhart Garratt Ltd** |
| Logie, Keith | City of Edinburgh Council |
| Long, Andrew | Red Rose Forest (W) |
| Lonsdale, David | Independent |
| Lotfhouse, David | London Borough of Merton |
| Lowe, Sam | Thomson Ecology |
| Lowes, Peter | Myerscough College |
| Mabbutt, Tom | Myerscough College |

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|---|---|
| MacDonagh, Peter | The Kestrel Design Group, ***USA*** |
| MacDonald, Bill | Forestry Commission Wales |
| Macgregor, Keith | Independent |
| **MacKenzie, Dr Rob** | **Lancaster University** |
| **MacQueen, Margaret** | **OCA UK Ltd** (T) |
| Mahon, David | MWA Arboriculture Ltd |
| Man, Flora | Leisure and Cultural Services Department, ***Hong Kong SAR*** |
| Mannix, Fiona | Royal Institution of Chartered Surveyors |
| Martin, Suzanne | Forest Research |
| Massini, Peter | Greater London Authority (W) |
| McCorkell, Charlie | Myerscough College |
| McCutcheon, Andrew | States of Guernsey |
| McGrath, Graeme | Myerscough College |
| McGregor, Duncan | Aberdeen City Council |
| McLeod, Alastair | Pinnacle Tree and Landscape Solutions Ltd |
| Melarange, Paul | P F Melarange Arboricultural Consultancy Ltd |
| Mills, Jonathan | Capita Symonds |
| Mitchell, Daron | Advanced Tree Services Ltd |
| Mitchener, John | JRM Tree Consultancy (W) |
| Moffatt, Prof. Andy | Forest Research |
| Mole, Imogen | National Association of Tree Officers |
| Monaghan, Douglas | Bartlett Tree Experts (W) |
| Monk, Kirsty | Oxford University |
| Morelli, Giovanni | Studio Progetto Verde, ***Italy*** |
| Morley, Katy | Hyndburn Borough Council |
| Motion, Alan | Independent |
| Muehlethaler, Prof. Urs | Bern University of Applied Sciences, ***Switzerland*** |
| **Nail, Dr Sylvie** | **University of Nantes, *France*** |
| Needs, Alex | Embridge Borough Council |
| Neilan, Chris | Epping Forest District Council |
| Noakes, Bob | Bartlett Tree Experts (W) |
| Nolan, Paul | The Mersey Forest (T) |
| **O'Callaghan, Dr Dealga** | **Western Power Distribution, Midlands, UK** |
| Ogilvie, James | Forestry Commission Scotland |
| O'Shea, Richard | The Environmental Partnership |
| O'Sullivan, Colleen | Myerscough College |
| Othman, Mandarwis | Independent |
| Parkin, Darren | Solihull MBC |
| Pearce, Michael | West Berkshire Council (W) |
| **Percival, Dr Glynn** | **Bartlett Tree Research Laboratories** |
| **Phillips, Ian** | **Independent Arboricultural Consultant** (W) |
| Phillips, Shaun | Derby City Council (W) |
| **Plante, Stephen** | **The Clay Research Group** (T) |
| Poepken, Stefanie | Institute for World Forestry, Hamburg, ***Germany*** |
| Potter, Andrew | Bartlett Tree Experts (W) |
| Poynter, Andy | Quaife Woodlands |
| Pozzi, Letiza | Demetra, ***Italy*** |
| Pursey, Tim | Independent |
| Quaife, Jim | Quaife Woodlands |
| Qureshi, Dr Salman | Birmingham City University (T) |
| Rahman, Asratur | University of Manchester |
| Raper, Chris | Arbconsultants (W) |

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| Ravencroft, Richard | Ravencroft Arboricultural Consultants |
| Read, Glen | Tree Solutions, ***Norway*** |
| Rees, David | Oxfordshire Woodland Project |
| Reike, Rob | The Parks Trust |
| Riches, Ben | ArbAdvice |
| Richmond, Simon | Arboricultural Association |
| Robbie, Gavin | A T Coombes Associates |
| **Roberts, Katie** | **Trees for Cities** |
| Roberts, Kate | Forestry Commission |
| **Rogers, Kenton** | **Hi-line Consultancy** |
| Rooney, Christopher | United States National Grid, ***USA*** |
| Rose, Ruth | Stratford-on-Avon District Council |
| Rose, Timothy | Coventry Council |
| Round, Les | Tree and Landscape Valuation Systems |
| Ruckledge, Gavin | Myerscough College |
| Russell Grant, Tom | Norfolk County Council |
| Rust, Steffen | University of Applied Science and Arts (HAWK HHG), ***Germany*** |
| **Sacre, Keith** | **Barcham Trees plc** |
| Sadler, Julie | Birmingham City Council |
| Sangster, Marcus | Forestry Commission |
| Sarkissian, Arbi | Bangor University |
| **Schroeder, Dr Herbert** | **Forest Service, *USA*** |
| Scott-Ellis, Tim | Evolve Tree Consultancy |
| Seabrook, Matthew | Telford and Wrekin Council |
| Secker Walker, Jo | Independent Research Consultant |
| Shallcross, James | University of Cumbria, Newton Rigg |
| Shao, Prof. Li | Institute of Energy and Sustainable Development |
| Shaw, Andrew | Leicestershire County Council (W) |
| Shervill, Andrew | Derby City Council (W) |
| Shields, Stephen | Shropshire Council |
| Shortis, Chris | Midland Forestry |
| Siddons, Richard | Forestry Commission Wales |
| Simons, Ken | Warwickshire County Council |
| Simpkin, Philip | Wycombe District Council |
| Simpson, Daniel | Tree Reports Ltd |
| Simpson, Moray | Wrexham County Borough Council |
| Simson, Alan | Leeds Metropolitan University |
| Single, Jamie | Caledonian Tree Company (W) |
| Sitch, Daniel | London Borough of Merton |
| Sjöman, Henrik | Swedish University of Agricultural Sciences, ***Sweden*** |
| Small, Peter | Middlesbrough Council |
| Šmid Hribar, Mateja | Anton Melik Geographical Institute ZRC SAZU, ***Slovenia*** |
| Smith, Alistair | London Borough Camden |
| Smith, Andy | Tree Health Consulting Ltd |
| **Smith, Jim** | **Forestry Commission** |
| Smith, Julie | Myerscough College (W) |
| Smith, Lester | Askham Bryan College |
| Sorensen, Chris | Forestry Commission |
| Sorensen, Tony | Ravencroft Arboricultural Services (T) |
| Stacey, Brian | Essex County Council |
| Steer, Luke | Treescapes Consultancy Ltd |
| Stitt, Byron | Myerscough College |

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|---|---|
| Stride, Gail | Bangor University |
| Strong, Neil | Network Rail Infrastructure Ltd |
| Taylor, Jonathan | Forestry Commission |
| Taylor, Neil | Westminster City Council (W) |
| Taylor, Robert | TEP |
| Taylor, Rupert | University of Reading (W) |
| Tello, Maria-Luisa | IMIDRA, ***Spain*** (W) |
| **Tenkir Shikur, Eyob** | **Addis Ababa Environmental Protection Agency, *Ethiopia*** |
| Thomas, Glyn | Cheshire Woodlands |
| Tierney, Martin | Amey LG Ltd |
| Torr, Nicholas | Myerscough College |
| **Townsend, Mike** | **The Woodland Trust** |
| Trewinnard, Jason | West Berkshire Council (W) |
| Unwin, Jonathan | Ravencroft Arboricultural Services (T) |
| van der Hulst, Jean-Paul | Nationale Bomenbank BV, ***Netherlands*** |
| van Krimpen, Romaine | University of Évora, ***Portugal*** |
| van Oss, Eric | Greenmax Urban Landscape Products |
| **van Wassenaer, Philip** | **Urban Forest innovations Inc., *Canada*** |
| Venners, Sarah | Independent (T) |
| Verth, Scott | Scottish School of Forestry, Inverness College, UHI |
| Vinsun, Michael | Vinsun Landscape (W) |
| Vojackova, Barbara | Mendel University, ***Czech Republic*** |
| Volp, Mike | National Association of Tree Officers |
| Wait, Christopher | Chris Wait & Associates |
| Walduck, Lisa | Greater London Authority (W) |
| Walkden, Eve | University of Southampton |
| Wall, Eamonn | Forestry Journal & Essential Arb |
| Wallace, Carrie | National School of Forestry |
| Waller, Dominic | Birmingham City Council |
| Wallis, Brian | RPS Planning and Development |
| Walter, Robin | Trees for Transition (W) |
| Ward, David | Birmingham City Council |
| **Warhurst, Pam** | **Forestry Commission** (W) |
| **Watson, Dr Gary** | **The Morton Arboretum, *USA*** |
| Webb, Jo Ann | LOCI Environment |
| Webley, Steven | City of Edinburgh Council |
| Webster, Paul | Forestry Commission |
| Welby, Mark | ACD Arboriculture (W) |
| **Wells, Matthew** | **NYC Department of Parks & Recreation, *USA*** |
| Wells, Peter | Barcham Trees plc |
| Welstead, Fenning | John Clegg & Co |
| West, Simon | Forestry Commission England |
| Wharton, Peter | Wharton Arboriculture |
| White, Jenifer | English Heritage |
| Whittet, Richard | Scottish School of Forestry |
| Wickison, Stephanie | Staffordshire County Council |
| Wightman, Claire | Scottish School of Forestry |
| Wigley, Kevin | Red Rose Forest (T) |
| Wijns, Thierry | Student |
| Wilkins, Peter | Marishal Thompson Group |
| Williams, Ian | Myerscough College |
| Williamson, David | Forestry Commission England SEEFD |

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| Wilsher, Clive | Solihull Metropolitan Borough Council |
| Wilson, Alan | UPM Tilhill |
| Wilson, Ted | University of Sheffield |
| **Winson, Adam** | **JCA Ltd** |
| Wishart, Keith | Forestry Commission Scotland |
| de Wit, Frans | Tree Ground Solutions, ***Netherlands*** |
| Wood, William | D W Tree Services |
| Woodbyrne, Eileen | Teagasc, ***Republic of Ireland*** |
| Woodham, Kevin | Bartlett Tree Experts (T) |
| Woodhouse, David | Shropshire Council |
| Worsey-Buck, Pherenice | London Borough of Bromley |
| Yu, Simon Lap On | Hong Kong Disneyland, ***Hong Kong SAR*** |

# Appendix 5: Trees, people and the built environment: the programme

Plenary conference sessions will be held in the Clarendon Suite – Ground Floor.

Parallel sessions will be held in the Clarendon Suite or the Warwick Suite – First Floor.

| Wednesday 13 April | |
|---|---|
| 10.00 | **Conference opens**<br><br>**Welcome:** Bill MacDonald, President, Institute of Chartered Foresters<br><br>**Introduction:** Dr Mark Johnston, Myerscough College, Conference Chair<br><br>**Message from HRH The Prince of Wales** |
| 10.10 | **Opening address**<br><br>Pam Warhurst, Chair, Forestry Commission |
| 10.30 | **Plenary session 1**<br><br>**Management of the urban forest**<br><br>**Introduction and Chair:** Dr Mark Johnston, Myerscough College |
| 10.35 | **Using research to justify and direct urban forestry programs in New York City**<br><br>**Matthew Wells**, Director of Tree Preservation, NYC Department of Parks and Recreation, USA |
| 11.05 | **Measuring the ecosystem services of Torbay's trees: i-tree Eco pilot project**<br><br>**Kenton Rogers**, Senior Consultant, Hi-line Consultancy, UK |
| 11.35 | **Strategic urban forest management using criteria and indicators**<br><br>**Philip van Wassenaer**, Principal Consultant, Urban Forest Innovations Inc., Canada |
| 12.05 | **Chaired panel discussion** |
| 12.35 | **Lunch ~ First Floor Exhibition Suite** |
| | Parallel sessions commence after lunch.<br><br>Please make your way to the session of your choice. |

| Wednesday 13 April – Afternoon | | | |
|---|---|---|---|
| 13.50 | **Parallel session 1a** (Clarendon Suite)<br><br>**Tree planting and establishment**<br>**Introduction and Chair: Keith Sacre,** Sales Director, Barcham Trees, UK, *representing The Arboricultural Association* | 13.50 | **Parallel session 1b** (Warwick Suite)<br><br>**Promoting green networks and human wellbeing**<br>**Introduction and Chair: Val Kirby,** Principal Specialist, Professions and Communities, Natural England, UK |
| 13.55 | **Results of a long-term project using controlled mycorrhisation with specific fungal strains on different urban trees**<br>**Dr Francesco Ferrini**, Professor of Arboriculture, University of Florence, Italy | 13.55 | **Exploring the role of street trees in the improvement and expansion of green networks**<br>**Dr Norman Dandy**, Research Scientist, Forest Research, UK |

| Wednesday 13 April – Afternoon (continued) | | | |
|---|---|---|---|
| 14.15 | **A review of factors influencing transplant survival of urban trees**<br>**Dr Glynn Percival**, Senior Plant Physiologist, Bartlett Tree Research Laboratories, UK, and<br>**Andrew Hirons**, Lecturer in Arboriculture, Myerscough College, UK | 14.15 | **Promoting wellbeing through environment: the role of urban forestry**<br>**Kathryn Gilchrist**, School of the Built Environment, Heriot-Watt University, UK |
| 14.35 | **Tree planting and establishment: has the research published in the last ten years helped us to improve?**<br>**Dr Gary Watson**, Head of Research, The Morton Arboretum, USA | 14.35 | **The potential of nearby residential trees to improve the subjective mental wellbeing of housing association tenants**<br>**Adam Winson**, Consulting Arboriculturist, JCA Ltd, UK |
| 14.55 | **Chaired panel discussion** | 14.55 | **Chaired panel discussion** |
| 15.20 | **Refreshment break ~ First Floor Exhibition Suite** | | |
| 15.50 | **Parallel session 2a** (Clarendon Suite)<br><br>**Trees and urban climate challenges**<br>**Introduction and Chair: Ian Phillips,** Independent Landscape Consultant, UK, *representing The Landscape Institute* | 15.50 | **Parallel session 2b** (Warwick Suite)<br><br>**Energy supplies and other management challenges**<br>**Introduction and Chair: Neville Fay,** Director, Treework Environmental Practice, UK, *representing The Ancient Tree Forum* |
| 15.55 | **The use of trees in urban stormwater biofiltration**<br>**Dr Liz Denman**, School of Land and Environment, University of Melbourne, Australia | 15.55 | **Advances in utility arboriculture research and the implications for the amenity and urban forestry sectors**<br>**Dr Dealga O'Callaghan**, Tree and Vegetation Manager, Western Power Distribution, Midlands, UK |
| 16.15 | **Quantifying the cooling and hydrological benefits of urban trees**<br>**Dr Roland Ennos**, Faculty of Life Sciences, University of Manchester, UK | 16.15 | **Assessment of the challenges and interventions made to develop the urban forest in Addis Ababa**<br>**Eyob Tenkir Shikur**, Addis Ababa Environmental Protection Agency, Ethiopia |
| 16.35 | **Chaired panel discussion** | 16.35 | **Chaired panel discussion** |
| 16.55 | **Day 1 Closing remarks:**<br>**Dr Mark Johnston,** Conference Chair | 16.55 | **Day 1 Closing remarks:**<br>**Shireen Chambers,** Executive Director, Institute of Chartered Foresters |
| 17.15 | **ICF AGM in the Warwick Suite (ICF Members only)** | | |
| 19.15 | **Conference Reception and Dinner, Birmingham Botanical Gardens.**<br><br>**Guest speaker: Tony Kirkham**, Head of the Arboretum and Horticultural Services, Royal Botanic Gardens, Kew<br><br>Pre-booked guests only. | | |

| Thursday 14 April | |
|---|---|
| 08.00 | **Registration opens in the Mezzanine for new (Day 2 only) delegates.**<br><br>Refreshments available in the First Floor Exhibition Suite for all delegates. |
| 09.00 | **Conference day 2 opens**<br><br>**Welcome to new delegates and introduction: Dr Mark Johnston**, Myerscough College, Conference Chair |
| 09.15 | **Plenary session 2**<br><br>**Governance of the urban forest**<br><br>**Introduction and Chair:** Dr Mark Johnston, Myerscough College |

| Thursday 14 April (continued) | | | |
|---|---|---|---|
| 09.20 | **Innovations in urban forestry governance in Europe**<br><br>**Dr Cecil Konijnendijk**, Professor of Green Space Management, University of Copenhagen, Denmark | | |
| 09.45 | **Governance and the urban forest**<br><br>**Dr Anna Lawrence,** Head of the Social and Economic Research Group, Forest Research, UK | | |
| 10.10 | **Chaired panel discussion** | | |
| 10.35 | **Refreshment break ~ First Floor Exhibition Suite** | | |
| 11.10 | **Parallel session 3a** (Clarendon Suite)<br><br>**Trees and urban design**<br>**Introduction and Chair: Angela Brady,** President Elect, The Royal Institute of British Architects, UK | 11.10 | **Parallel session 3b** (Warwick Suite)<br><br>**Multipurpose management and urban futures**<br>**Introduction and Chair: Janet Askew,** Head of the Department of Planning and Architecture, University of the West of England, UK, *representing The Royal Town Planning Institute* |
| 11.15 | **Does beauty still matter? Aesthetic and utilitarian values of urban trees**<br>**Dr Herbert W. Schroeder**, United States Department of Agriculture, Forest Service, USA | 11.15 | **'Natives versus aliens' – the relevance of the debate to urban forest management in Britain**<br>**Dr Sylvie Nail**, Professor of British Studies, University of Nantes, France, and<br>**Dr Mark Johnston**, Research Fellow: Arboriculture and Urban Forestry, Myerscough College, UK |
| 11.35 | **Urban trees and the green infrastructure agenda**<br>**Martin Kelly**, Managing Director, Capita Symonds, UK | 11.35 | **Strategies for exploring urban futures in, and across, disciplines**<br>**Dr Rob MacKenzie**, Reader in Atmospheric Science, Lancaster Environment Centre, Lancaster University, UK |
| 11.55 | **Chaired panel discussion** | 11.55 | **Chaired panel discussion** |
| 12.20 | **Lunch ~ First Floor Exhibition Suite** | | |

| Thursday 14 April – Afternoon | | | |
|---|---|---|---|
| 13.30 | **Parallel session 4a** (Clarendon Suite)<br><br>**The value of communities in successful urban greening**<br>**Introduction and Chair: Jim Smith,** Project Development Manager, London Region, Forestry Commission, UK | 13.30 | **Parallel session 4b** (Warwick Suite)<br><br>**Resolving conflicts with urban infrastructure**<br>**Introduction and Chair: John Lockhart,** Chairman, Lockhart Garratt, UK, *representing The Royal Institution of Chartered Surveyors* |
| 13.35 | **Working with communities to realize the full potential of urban tree planting: a sustainable legacy**<br>**Katie Roberts,** Projects Director, Trees for Cities, UK | 13.35 | **Investigation into the interactions between closed circuit television and urban forest vegetation in Wales**<br>**Stuart Body**, Directorate of Environment and Regeneration, Flintshire County Council, UK |
| 13.55 | **Public participation in urban tree cover**<br>**Mike Townsend,** Senior Advisor for Specialist Communications and Evidence, The Woodland Trust, UK | 13.55 | **What price retention? Current research relating to domestic subsidence in the UK**<br>**Margaret MacQueen**, Consultant Arboriculturist, OCA UK Ltd, UK, and<br>**Stephen Plante**, Director, Clay Research Group, UK |
| 14.15 | **Chaired panel discussion** | 14.15 | **Chaired panel discussion** |
| 14.35 | **Refreshment break ~ First Floor Exhibition Suite**<br><br>This is your final opportunity to talk to the companies who have supported this conference and to read the posters from organisations whose research is vital to urban greenspacing. | | |
| 15.05 | **Plenary closing session**<br><br>**Introduction and Chair: Dr Mark Johnston**, Conference Chair | | |

| Thursday 14 April – Afternoon (continued) | |
|---|---|
| 15.10 | **Urban/rural ecology in the transition to the 'ecological age'**<br><br>**Peter Head**, Former Chairman of Global Planning and currently Consultant to Arup, UK |
| 15.35 | **Chaired discussion** |
| 15.55 | **Summing up: Dr Mark Johnston**, Conference Chair |
| 16.00 | **Closing Words: Shireen Chambers,** Executive Director, Institute of Chartered Foresters<br><br>**Conference closes** |

# Appendix 6: Conference sponsors

## Conference Host:

**The Institute of Chartered Foresters (ICF)** is incorporated by Royal Charter as the only professional body in the UK to award chartered status to those working in forestry and arboriculture. Its members work in the public, private and third sectors, as well as in education and research.

## Headline Sponsors:

**Bartlett Tree Experts** offers a broad range of services including arboricultural and woodland management, contracting, consulting, research and development. We are committed to helping tree owners maintain beautiful, healthy trees. No matter the size or scope of your tree, shrub or woodland care needs, we work with you to protect and enhance your landscape.

**Myerscough College** is widely regarded as the leading UK higher education institution for the study of arboriculture. Myerscough pioneered the UK's first Foundation Degree and Honours Degree in the subject. It developed the first part-time online degrees and, most recently, the first Masters Degree in Arboriculture and Urban Forestry.

**Media Partner:**
Published monthly, ***Forestry Journal*** brings all the latest news, reports and opinions to keep you up to date in what is a very diverse industry. The quarterly sister publication ***EssentialARB*** contains a lively mix of industry articles including product reviews, case studies, company profiles and event reports and is required reading for all in the arboriculture industry.

## Other Sponsors:

**Conference Brochure Sponsor:**
**Geosynthetics Ltd** designs, supplies and installs a range of geotechnical solutions for all types of civil engineering and building projects. Our products range from simple geotextiles and geogrids to tree root protection systems, reinforced earth retaining structures and all types of impermeable geomembranes. We are also the UK and Ireland distributor for the Deeproot Silva Cell Tree and Stormwater Management System.

**Conference Student Sponsor:**
**Barcham Trees Plc** has been growing trees for over 25 years and specialises in containerised trees ranging from 3 to 12 m in height, all grown in its patented white Light Pots™ to ensure a vibrant and quick-to-establish root system after planting. With a stock of over 450 varieties and a production of 125 000 container trees per year, its tree nursery is the largest of its type in Europe. Barcham Trees sponsored 20 student places.

**Conference Delegate Bag Sponsor:**
**RPS** has expertise in all aspects of the planning and development process from site identification to implementation to management. We offer planning, design and environmental services from offices across the UK and Ireland. Our Arboriculture and Landscape consultants have an enviable reputation for providing expert advice based on their detailed understanding of statutory legislation and professional guidance notes. For more information email: wallisb@rpsgroup.com

Our urban forests, the trees and woodlands in and around our towns and cities, provide numerous environmental, economic and social benefits. As the most important single component of green infrastructure these trees have a vital role to play in promoting sustainable communities. In April 2011, for the first time in Britain, the relevant professional bodies concerned with urban trees and the built environment came together to hold a major international research conference. With some 400 delegates, 'Trees, People and the Built Environment' was one of the biggest tree conferences ever held in Britain. Hosted by the Institute of Chartered Foresters, the event featured leading expert practitioners and research scientists from around the world presenting papers that 'showcased' the very latest research and innovative practice. These conference proceedings are expected to make a significant contribution to the literature on urban forestry and urban greening.

TREES, PEOPLE AND THE BUILT ENVIRONMENT


Forestry Commission

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