climate change

Scotland's centre of expertise connecting climate change research and policy

Building Resilience in Scotland's Urban Tree Populations

Andy J Moffat

July 2015

1. Key points

- Ageing tree populations and the current and likely future impact of pests and diseases are currently changing attitudes and operations more than climate change
- Storms and recent case law involving human injury/death are increasing the adoption of risk management principles for city trees
- Availability of resources is currently limiting resilience-building strategies, though species diversification and establishment of novel species is taking place
- Scottish cities are showing significant interest in more efficient re-use and marketing of their arboricultural arisings, for timber, firewood, biomass and horticultural uses, though the primary motivation is financial
- There is a need to develop a better collective understanding of the value of trees across local authority departments

2. Introduction

This paper examines the current position of urban tree management and the extent to which climate change resilience is being addressed. It provides feedback from interviews with six of the seven Scottish city arboricultural and greenspace officers and their responsiveness to the need for climate change adaptation and resilience building. It offers reflections on how policy support for the arboricultural and urban forestry sector can be more effective in future. One strand of CXC's planned work programme has involved analysing the implementation of climate adaptation actions "on the ground" in Scotland. This paper has not been specifically requested by a Scottish Government policy team, but presents policy-relevant interim findings from CXC's ongoing work programme.

3. Study context

Scottish towns and cities have probably contained trees since they evolved in the first place - a plan of Edinburgh[1] painted by Joris Hoefnagel (1542-1601) clearly shows trees within the

[1] https://files.list.co.uk/images/2011/01/26/Old-Edinburgh-Map.jpg

walled city in the 16th Century whilst the map of Aberdeen (c. 1661)[2] by James Gordon (1615-1686) depicts an intimate association of houses and garden trees (though there is no evidence of street trees at this time). Trees probably provided a visible and spiritual link to the countryside, and were regarded as valuable components of the urban landscape. Almost certainly, fruit trees in private gardens were cultivated to provide food, and some may have been exploited for firewood.

The areal extent and actual number and type of trees and woodlands in Scottish towns and cities today is unknown as there is no national process for these data collection. As an estimate, the first analysis of urban greenspace extent in Scotland (areas of more than 3,000 people with a 500 m buffer around the settlement area) was estimated by Greenspace Scotland (2009) at 84,870 ha: 30% domestic gardens, 28% natural and semi-natural greenspace, 9% public parks, 15% amenity greenspace, 13% sports areas and 5% other (play spaces, allotments, green corridors, burial grounds and civic spaces) (Davies et al., 2009). Most but not all of these urban land classes are likely to contain trees to some extent, and this classification doesn't include roads and streets where many urban trees are located. For example, a recent estimate suggests there are 8,550 street trees in Edinburgh (Edinburgh City Council, 2014) amongst an estimated total of 638,000 (Hutchings et al., 2010). The disposition of different types of greenspace, and hence opportunities for trees and woodland cover varies significantly between urban areas in Scotland, the result of differing topography, geology and landscape evolution. Figure 1, from Davies et al. (2011), shows this well.

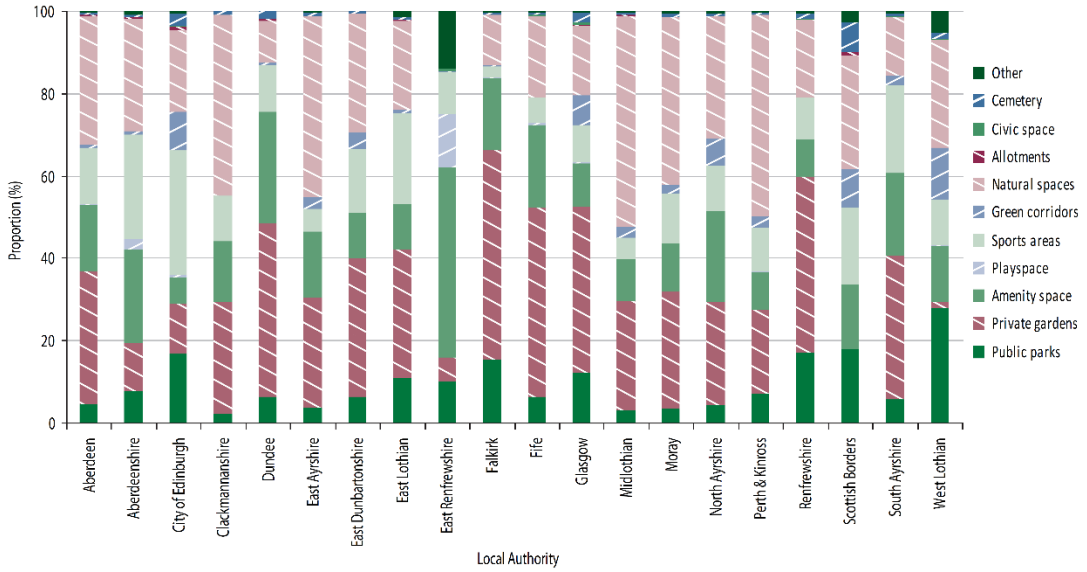

Figure 1. Urban greenspace composition within Scotland.

[2] http://maps.nls.uk/view/74400885

Interestingly, the classification adopted by Greenspace Scotland doesn't include urban woodlands or forests, yet these exist in significant amounts in and around some Scottish cities. Indeed, the Scottish Government 'Woodlands In and Around Towns' (WIAT) initiative recognises the importance of this type of greenspace for public benefit. Since 2005, WIAT has promoted the increase and improvement of woodland at these locations through the allocation of £50 million for relevant projects. This has resulted in 11,000 hectares of neglected woodland being brought into active management, and 1,400 hectares of new urban woodland created (Forestry Commission Scotland, 2011).

In this small study, Scottish cities were selected as having the greatest opportunity to demonstrate how resilience building was being taken forward - several have already published Tree Strategies (see Section 7.1). Focus on this sample group was considered to be more efficient in identifying opportunities to resilience building in urban areas than seeking to erect a sampling strategy across the range of different sized towns and cities. However, it will obviously be necessary to consider the applicability of the study findings in context.

4. Urban tree and woodland ecosystem services

The Millennium Ecosystem Assessment (2008) and UK National Ecosystem Assessment (2011) frameworks have allowed us to examine possible goods and services that ecosystems can, or could, deliver. Following the model for forestry (Quine et al., 2011), Table 1 has been produced to demonstrate goods and services particularly relevant to urban trees and woodlands in Scotland.

Provisioning Services	**Examples of delivery**
Urban woodlands for timber production	Provision of cut timber materials for use in commercial and domestic enterprises
- for construction / substitution	Use of timber as an alternative for other building materials such as steel and concrete in order to reduce use of fossil fuels
- for bio/woodfuel	Arboricultural arisings (e.g. chips, stumps and roots) as fuel for heat and power plants, as domestic firewood
- for horticulture	Arboricultural arisings as mulch materials
Forests for non timber products	Non-timber forest products (NTFPs) for domestic use, for example berries, nuts, honey and fungi
Cultural services	**Examples of delivery**
social cohesion, personal strength	Trees and woodlands are valuable for personal enlightenment, and as places or catalysts for social activity and cohesion
amenity/ recreation/ health	Urban woodlands are open to the public for the enjoyment of outdoor pursuits and recreational activities.
landscape, historic environment	Trees and woodlands increase the diversity of urban landscape character
education	Urban woodlands are increasingly harnessed for their educational value in 'Forest Schools'
inspiration for the arts	Trees have been perpetual motifs in fine art, and influenced many other art forms

Regulating Services	**Examples of delivery**
pollution mitigation	Capture of atmospheric pollutants in tree canopies and consequent reduced exposure for humans, buildings etc. Woodland cover to stabilise contaminated brownfield land and hinder the pathways between source and receptors
soil protection	Tree cover can offer protection from soil erosion and slope failure
flood and water protection (as part of SUDS)	Trees and woodlands moderate rainfall events and river and stream hydrographs, delaying and reducing flood events
carbon sequestration	Urban trees and woodlands can help store terrestrial carbon in above-ground components and soils
climate (change) mitigation	Tree canopy cover can provide cooling and shade for urban dwellers and help dampen the effects of the urban heat island
archaeological protection	Trees can prevent destructive agents from damaging or destroying archaeological evidence
Supporting services	**Examples of delivery**
Soil formation, nutrient cycling, water cycling, oxygen production	Trees facilitate soil formation and other biogeochemical processes essential to life
biodiversity	Trees and woodlands provide habitat for a wide range of fauna and flora

Table 1. Ecosystem goods and services from urban trees and woodlands

Traditional services such as enhancing landscape character are included in the Table, but there are many others. Some, such as carbon sequestration, biomass production and climate mitigation, are particularly relevant to the role of urban trees in helping society adapt to climate change. There has been considerable research in seeking to understand the potential and actual delivery of many of these services - two recent reviews for greenspace or Green Infrastructure in general have been produced by Bell et al. (2008) and Forest Research (2010). Others have focused on delivery by urban forests, e.g. Thomas and Geller (2013). Indeed, valuation tools based on urban woodland ecosystem services such as 'i-Tree'[3] have been tested in both Edinburgh (Hutchings et al., 2012) and Glasgow (Rumble et al., 2015). Recent climate change adaptation and planning policies make specific reference to the role of street trees and their support for "helping Scotland to mitigate and adapt to climate change" and refer to specific ecosystem services such as cooling, flood alleviation and recreation (Scottish Government, 2014a; 2014b). Nevertheless, the utility of the ecosystems framework in arboriculture and urban forestry at city level in Scotland has yet to be fully established.

5. Tree and woodland vulnerability

To date, most interest in tree and woodland vulnerability, and adaptation responses to increase their resilience, has come from the forestry and conservation sectors. A recent review has identified the largest likely effects of climate change on Scottish forestry (Ray, 2008). Scottish Natural Heritage (SNH) have also reviewed the likely impacts of climate change on nature, including native woodland (SNH, 2012). Forestry Commission Scotland (FCS) has had policies related to climate change for several years, the latest of which are presented in the Climate Change Programme (FCS, 2013). However, there appears no national equivalent focal point from which Scottish urban tree resilience is directed.

For Scottish woodland and forest trees, climate change is expected to pose several risks, based on the following impacts:

- summers will become warmer and winters milder;
- the rainfall distribution will change, leading to drier summers in eastern Scotland, particularly the eastern and south-eastern lowlands, and wetter winters in eastern Scotland;
- increased frequency of high-intensity rainfall leading to increased occurrence of landslips, wetter soils, soil erosion, and sedimentation of watercourses;
- decreased winter cold, and fewer frost days;
- changes in wind climate, with more frequent strong winds

from Ray (2008)

[3] https://www.itreetools.org/

The main effects on trees from these changes are expected to be on tree survival and growth, especially for species close to their ecological limit. In addition, changing climate is expected to affect the likelihood of attack by pests and pathogens (see below). Extreme weather events such as droughts, floods, storms or wildfires will also impact on Scottish trees to variable degrees.

Trees in urban woodlands and forests can be expected to experience similar changes in climate over the next few decades. However, there are some particular differences between rural and urban microclimates, the most well-known of which is the Urban Heat Island (UHI) effect. This is due to the absorption of heat by roads and buildings with the result that cities can be several degrees warmer than the surrounding countryside, especially at night. The UHI effect has been noted and studied in several Scottish cities, including Glasgow (Emmanuel and Krüger, 2012) and Edinburgh (Mackinnon, 2013). So urban trees, especially those in streets, are likely to experience warmer conditions than their rural counterparts. Another significant difference is the amount of plant-available water provided by urban soils: compared to rural locations, many urban trees suffer from restricted rooting and grow in artificial or very disturbed soil substrates with poor available water capacity. Hence, drought can be exacerbated in these locations during periods of low rainfall. In contrast, waterlogging is often found in urban soils where compaction has occurred, or where poor drainage design has led to water ponding after heavy rainfall.

In addition to changing climate, trees of many species in Scotland appear to be increasingly susceptible to attack by insect pests and microbiological pathogens. In some cases, new threats have been due to plant trade, notably in the raising of trees in nurseries in mainland Europe where certain pathogens are endemic, and then the importation of the trees to be planted out in the UK. In other cases, the spread and damaging effects of pathogens may be exacerbated by climate change. Again, most study of these effects in Scotland has been on forest trees and those in native or semi-native woodlands. However, an important review of possible impacts of climate change on urban tree pests and pathogens was provided by Tubby and Webber (2010). This identified that "climate change is likely to lead to increased physiological stress in trees growing within urban areas that, in turn, will predispose trees to attack from a range of pests and pathogens. Climate change will also present a more favourable environment for many native and non-native organisms with the potential to cause harm."

In general, urban trees therefore seem to be at risk from the same general range of external threats as trees planted in countryside woods and forests. But there are two other sets of risks which are particular to the urban landscape. The first set reflects the fact that cities are dynamic and are constantly changing and regenerating. Development, changing road

layouts, installation of utilities, flood relief schemes[4] (and trams in Edinburgh[5]), and the changing fashions of garden design and horticulture all play a part in putting different elements of an urban tree population at risk. The second set relates to the legacy of decisions about urban trees taken in previous times. Air pollution, the use of salt for road de-icing and preference in particular tree species for landscape enhancement has meant that many towns and cities are now characterised by an ageing population of a limited number of tree species, some of which are now vulnerable to changes in climate or attack by pests and pathogens - or both! In Edinburgh, it is estimated that 15% or nearly 100,000 of its trees are deemed to be in a critical, dying or dead condition (Hutchings et al., 2012)[6].

Finally, urban trees and woodlands are vulnerable to budgetary restraints and cutbacks, especially in recent recessionary times. A study for the Heritage Lottery Fund (2014) reveals that the Scottish Unitary Authorities that contributed to the study (nine out of 32) recorded an average reduction in the Parks budget of 18.2% from 2010 to 2012, and indicated an expectation of a further 10.8% reduction from 2014 to 2016. This general downward trend must be considered in the context of any scientifically drawn or policy related desire to perform resilience building activities for urban trees and woodlands.

6. Study methodology

This report explores what resilience-building means for urban trees in Scottish cities. It is based on a review of policies and practices in the six largest cities. The study is based on literature review together with structured interviews with relevant personnel in each of the selected cities (Table 1). Three of these were face-to-face in the city arboricultural or parks department offices, and three were conducted over the telephone.

The interviews sought to clarify and gain evidence on the extent to which those responsible for city trees (including urban woodland and forest) were aware of the nature of the impacts discussed above, and to what extent they were able to respond in order to build resilience in the tree populations under their management. Building resilience is a major theme running through the Scottish Government Adaptation Programme (Scottish Government, 2014b), although the term 'resilience' is not defined. For the purpose of this study, the definition put forward by the Rockefeller Foundation (2009), as reproduced by the Royal Society (2014), is used as one with broad applicability:

[4] http://www.bbc.co.uk/news/uk-scotland-edinburgh-east-fife-15838382
[5] http://www.hortweek.com/trees-lost-good-edinburghs-leith-walk-wake-tram-debacle/arboriculture/article/1312917
[6] http://www.tree-time.com/about/

> 'The capacity of individuals, communities and systems to survive, adapt, and grow in the face of stress and shocks, and even transform when conditions require it'.

Thus, resilience was studied in the context of preparedness for climate change, but also the other main threats discussed above. A major objective was also to examine resilience in the context of political (local), economic and social drivers, and to understand the constraints to resilience-building, and/or the opportunities for doing so. Opportunities included improving financial security for adaptation activities through diversification of income, notably by selling timber and timber products (e.g. fire wood, biomass chips). In this respect, the study also encompassed city attitudes and actions towards climate change mitigation, though this was not the main theme of the research project.

The willingness or ability to transform from the status quo was also explored through the questioning. A final objective was to investigate the nature of information or knowledge used by city arboriculturists to build resilience, and the distance in communication between practitioners and the research and policy communities. Interviews took between 45 minutes and one hour, 45 minutes to complete, depending on the available time that interviewees could give. Interviews were recorded and transcribed, and then analysed for relevance to the project research questions.

The preliminary results of the study were shared and tested amongst a group of twenty two Scottish urban tree professionals at a meeting in Glasgow on 12th June. A presentation was given to the Scottish Tree Officers Group (STOG) and time was allowed for feedback during and after the event.

7. Results

Without exception, interviews generated invaluable information on how city managers currently approach arboricultural tree care and how they are adapting, or have adapted, their operations to take account of climate change and other impacts. There was a tangible energy around the subject of tree care, with all respondents taking a long term viewpoint in respect of the work they did. Although differences emerged between cities in the degree to which they have been able to take climate change related issues forward, a general similarity in ambition was apparent. Important points are grouped under the following main headings:

- modern arboricultural practice
- importance of climate change in affecting practice
- constraints to and opportunities for future resilience building

	Date	Interviewees	City Department
1	3rd March 2015	Eric Hamilton,	Forestry Officer, Environment, Dundee
		Alison Anderson	Greenspace Manager, Environmental Management, Dundee
		Lucy Ryan	Greenspace Officer, Environmental Management, Dundee
2	4th March 2015	Paul Vine	Trees and Woodlands Officer, Edinburgh
		Keith Logie	Parks Strategy Manager, Edinburgh
3	5th March 2015	Richard Nicholson	Arboricultural Officer, Communities, Housing & Infrastructure, Aberdeen
4	6th March 2015	Andy Murray, Graeme Golding	Natural Environment Officers (Arboriculture & Woodland), Glasgow
5	11th March 2015	Amanda Ophof	Forestry Assistant, Highland Council, Inverness
6	26th March 2015	Fiona Melville	Tree and Woodland Officer, Stirling

Table 2. Diary of interviews

7.1 Modern arboricultural practice

Care of street and woodland trees in Scottish cities requires both a look back at the past and an eye to the future. Respondents were very conscious of the large tree legacies they had responsibility for, many of which dated to Victorian times. In significant respects, it is the decisions made in the past which have helped to create the city's identity, for example in the choice of elms as a major component of trees in Edinburgh, Dundee and Aberdeen. Tree lined roads, avenues and parkland tree belts consisting of single tree species are also features which were designed purposefully and which now impose themselves on the city as large landscape features. It was evident that some arboricultural officers saw it as their duty to uphold city tree traditions as far as it was possible or practicable. This implies that for many, city trees have a particular and important function in the landscape, and care and maintenance are deployed to this end. Dundee City Council (2009) state this well:

"The management of Dundee's trees and woodland management has focused mainly on providing an attractive resource for residents (whilst generating small amounts of income from marketable produce including timber)."

On the other hand, all arboricultural officers recognised that their jobs were not solely about preservation, and that this policy would fail in the face of pressures such as climate change and pests and pathogens. It was clear that they wished to respond to these new challenges and to maintain or even expand city tree populations during the time they had responsibility for them.

Some cities have specific Tree and Woodland Strategies or Action Plans (for example, Edinburgh (Edinburgh City Council, 2014), Aberdeen (Aberdeenshire Council, 2005), Dundee (Dundee City Council, 2010)), Stirling & Clackmannanshire (Stirling & Clackmannanshire Councils, 2014), whilst others are actively developing them (e.g. Inverness). Others have tree and urban forestry policy statements or objectives, for example Dundee (Dundee City Council, 2009) and Stirling (Stirling Council, 2012), or authoritative guidance which includes urban tree issues (Glasgow City Council, 2013). All these publications make some reference to climate change adaptation, mitigation or both, though none are centred on these issues. Nevertheless, all are valuable in identifying the importance of trees for urban liveability, now and in the future.

A consistent driver for modern arboricultural management is related to risk, perceived or real, of damage to life and infrastructure. In some quarters within city authorities, trees appear to be regarded as assets of questionable value. Under both civil and criminal law, city councils have responsibilities for the health and safety of those on or near land on which trees are situated and have potential liabilities arising from the falling of a tree or branch. The civil law gives rise to duties and potential liabilities to pay damages in the event of a breach of those duties. There is also risk of prosecution in the event of an infringement of the criminal law (National Tree Safety Group, 2011). This has led to the installation of asset management systems for city trees in Scotland[7], such that safety inspections can be programmed in relation to danger to human health and property damage. Several cities already have these systems installed, others are in the process of doing so, though lack of resources is slowing progress of surveying all city trees for addition to the database behind the system. Recent storms (generally perceived to have increased significantly in the last five years) and an ageing tree population more prone to storm damage, are reasons why these systems are now so prevalent. In addition, shrinking resources have focused managers' minds towards stratifying tree safety inspections based on risk and prioritising inspections where these matter most.

As well as managing risk, other relevant arboricultural responsibilities include maintaining and replacing existing tree stocks, resisting pressures to reduce tree numbers and seeking opportunities to plant more trees. There has been a trend towards losing more street trees than are planted or replanted (Edinburgh City Council, 2014), in line with that in other parts of Britain (e.g. Britt and Johnston, 2008).

The ecosystem framework (e.g. as advanced by UK National Ecosystem Assessment (NEA), 2011) does not appear to be important as a general driver for considering Scottish urban

[7] For example: http://www.pbinsight.co.in/products/data-management/business-intelligence1/confirm1/ and http://www.ezytreev.com/

tree priorities and policy drivers. However, in Edinburgh and Glasgow, information from the i-Tree surveys has catalysed ecosystem thinking in these cities, and encouraged other cities to think about commissioning an i-Tree survey in the future, if resources allow. The ecosystem framework is conspicuous in its absence from the strategy documents briefly described above, though most predate the publication of the NEA.

Further information on the role of local authorities in managing trees in Scottish towns and cities is provided in Van der Jagt and Lawrence (2015).

7.2 Importance of climate change in affecting practice

Most respondents were aware of climate change as being of national relevance but suggested that it was difficult to ascribe particular changes in weather to climate change in their cities. Storms were most commonly linked to a climate change driver, and only in Edinburgh were droughts and heavier rainfall events also identified as of probable climate change origin. Thus, tree condition and growth were largely considered to be unaffected by climate change to date, though heightened public awareness was mentioned as a possible reason why cities needed to be more vigilant with regard to storm damage (see above).

Irrigation doesn't generally take place and isn't yet seen as a necessary step in tree establishment. However, there was widespread interest in the use of cellular tree installation systems[8] which facilitate rainwater recharge into the tree rooting zone, and some experience (e.g. in Dundee, Glasgow, Stirling) of using them in a limited way. A significant study examining the retrofitting of these and other green infrastructure engineered systems has recently been undertaken in Glasgow (Irving et al., 2014).

Of greater importance to arboricultural officers was the current and likely future impact of tree pests and diseases, though some linked the impact of some of these to climate change. In the east of the country, Dutch Elm Disease (*Ophiostoma novo-ulmi*) is considered the greatest threat to city tree landscapes, given that wych elm constitutes 19% of "all the native tree area in Dundee City" (Dundee City Council, 2009) and 4.5% of total tree cover in Edinburgh (Edinburgh City Council, 2014). Other diseases mentioned as of future significance were Chalara ash die-back (*Hymenoscyphus fraxineus*), Dothistroma needle blight in pines (*Dothistroma septosporum*), Phytophthora diseases of larch (*Phytophthora ramorum*) and Lawson cypress (*P. lateralis*). All these diseases are terminal and thus could have major impacts on city trees.

All respondents expected climate change to have an impact on their sector in future years, most notably in affecting the health and viability of tree species, especially those at the edge

[8] For example: http://greenblueurban.com/product_item/arborflow/ or www.infragreen-solutions.com

of their current natural ranges. Indeed, it was considered that some species might benefit from warmer weather conditions (e.g. Norway maple and London plane in Glasgow). But the main concerns centred around the limited species diversity and ageing tree populations that make up most of the cities' street trees. The i-Tree surveys in Edinburgh and Glasgow reveal that in the former, over 65% of city trees are from only ten species, with two (sycamore and holly) each constituting over 10%. In Glasgow, ten species make up 63% of the total, again with two (ash, hawthorn) each constituting over 10%. Respondents were well aware that the legacy of limited tree species now posed a risk that required mitigation through introduction of a wider species mix. And there appeared a universal acceptance that city arboriculturists could and should meet the challenge through selection of novel tree species to explore in limited plantings. The Royal Botanic Gardens in Edinburgh were referenced with respect to the experience of growing non-native species and the opportunity to draw from this in choice of possible new species for city streets.

In all cities, choice of tree species was not restricted to native ones, with respondents demonstrating a desire to grow trees that would survive into new climatic periods whilst continuing to deliver amenity and landscape benefits. These were seemingly the principal objectives for species choice. Nevertheless, in many cities, a tendency to draw more from native species was reported, in line with traditional guidance on the benefits of using them (Scottish Executive, 2002) along with tree policies and city strategies which acknowledged the value of urban woodlands for biodiversity and wildlife habitat.

The value of urban trees for cooling and shade as ecosystem services (Table 1) relevant to climate change are picked up in some recent Scottish reports and policy documents (e.g. Dundee City Council, 2010; Emmanuel, 2013; Edinburgh City Council, 2014; Irving et al., 2014). However, the city arboriculturists broadly rejected these issues as pertinent drivers in current tree management. Instead, they reported that in Scotland, it is the *reduction* in light caused by street trees that some residents find disagreeable and for which they seek redress. Similarly, whilst the role of urban trees for carbon sequestration is acknowledged in city strategies, interview respondents identified no change in management practices that reflected this driver, such as change in silvicultural regime for urban woodlands. Whilst they accepted that trees had a part to play in reducing (fossil fuel) carbon emissions, city arboriculturists saw this as a by-product of management for primary purposes such as amenity. Nevertheless, Aberdeen City has registered one urban woodland project under the Woodland Carbon Code[9] and it is possible that more will follow across other Scottish cities.

[9] https://mer.markit.com/br-reg/public/project.jsp?project_id=103000000004442

A management objective which appears to support Scottish Government climate change mitigation policy is that of using arboricultural arisings for renewable energy. A recent study (O'Neill et al., 2010) has estimated just over 700,000 tonnes of arboricultural arisings are produced in Scotland each year, with over half being generated or managed by local authorities. Increasingly this is being considered for its value as feedstock for bioenergy generation and firewood, whilst timber is sold on the open market. Good examples were given from several of the cities canvassed, and some are taking on new staff to explore how to develop these income streams further. Such practices mirror the guidance for best practice in use of woody materials as given in the UK Bioenergy Strategy (Department of Energy & Climate Change, 2012), but interview respondents made the point that it is for financial rather than climate change reasons that such developments are being followed. Indeed, several made the point that such income streams could augment or replace diminishing central budgets and thus allow mainstream arboricultural management to continue. In this sense, sales of biomass are helping to build *economic* resilience with respect to preservation of city tree stocks. Nevertheless, start-up funding and support at senior level were still lacking in some places.

7.3 Constraints to and opportunities for future resilience building

The main constraints to building future resilience appear to rest on six main issues.

7.3.1 Core Funding: In line with national data (Heritage Lottery Fund, 2014), all city respondents identified quite significant cutbacks or realignments in their budgets. In some cases, this largely restricted activities to reactive asset management (e.g. after storms) and essential safety inspections, with little left for proactive planting programmes. One city reported that its ability to do tree management on city property (e.g. a school playground) depended on budget allocation from the department who managed the property in question, and pointed this out as a hurdle to progress. A different city had exploited funding through the Scottish Rural Development Programme (SRDP), though there had been 'problems' with this. Similarly, another city pointed to the interruption in Scottish Government WIAT funding, but looked forward to its renewal so that more proactive projects could be tackled. In addition to income from the sale of wood products (see above), one city sold its tree management services to private organisations and residents and another reported that it sometimes sought payment for tree pruning that residents insisted upon. Several pointed to the possible opportunities that i-Tree surveys might give, by putting economic value to the range of ecosystem services that a city's trees provide. It was hoped that this might open up or renew funding at an appropriate level in order to ensure delivery of such services. Edinburgh City Council has recently helped to launch a

public-private partnership (Tree Time Edinburgh[10]) in an attempt to raise private sponsorship for tree management. However, the overall impression gained was one of entrenchment, though all those interviewed remained positive about what could and needed to be done.

7.3.2 Leadership and Support: there was a general feeling that city trees were taken for granted by elected members and more senior authority staff, who didn't understand the benefits of trees, or the work required for delivery of such benefits. Tree issues were below the 'political radar'. In addition, there was little tangible linkage with climate change at senior level, despite some references in city tree strategies. Others reported confusion and contradiction between planning and environment departments in respect of tree policy. One respondent also pointed to a perceived distance between Scottish Government policy makers and what arboricultural managers were expected to do on the ground - there was no 'follow up' and this was regretted.

7.3.3 Interaction with other authorities: several city arboriculturists identified that opportunities for tree preservation and introduction of new trees was very dependent upon a good professional understanding with other city departments, especially planners, landscape architects and road engineers. Some reported relatively good working relationships, others less so. Engineers, in particular, were identified as having a relatively poor understanding of trees in relation to structures and tended to be risk averse. However, good working relationships could do much to alleviate misunderstanding and this opened up possibilities for tree planting, for example in new development or road schemes. Those arboriculturists interviewed demonstrated a proactive approach to engaging with their local authority colleagues, and the impression was given that this was entirely necessary for trees to be considered effectively when plans for new development took place. Only one respondent indicated a partnership approach with discussions taking place early in the planning process, though others may occur. This probably reflects the comparatively lowly position where tree management is placed, as discussed above. Loss and rapid changes in local authority staff were also put forward as constraints to progress.

7.3.4 Availability of land: new tree planting is largely restricted to new developments, and there are only limited opportunities to increase the diversity of tree species in a city. Tree officers often have to make the case for inclusion of trees in new schemes, and it appears that they succeed where they can. Species choice is chiefly dictated by the developer though arboricultural officers seek to negotiate for those that they consider will endure future conditions. Recent interests in Sustainable Urban Drainage Schemes (SUDS) also has the potential for release of land with opportunities for tree planting though one city

[10] http://www.tree-time.com/

reported a current loss of trees as a result of such schemes, with ambitions to redress this balance in the future. There is perhaps more opportunity for planting in the peri-urban zones surrounding the city, with some cities seeking to encourage the establishment of woodland on surrounding agricultural land for recreational purposes and others such as Glasgow interested in exploring the role of woodland in reducing flood risk there (Forest Research, 2013).

7.3.5 Attitudes of residents: Interview respondents painted a picture of a fairly traditional approach to trees amongst most city residents. Most appeared to take trees for granted unless they were perceived as causing nuisance, particularly through aphids and honeydew or by blocking light to housing. There is no Tree Warden Scheme[11] (as run by the UK Tree Council) in Scotland, and as yet only infrequent community engagement through joint projects, although a few examples were offered[12]. Several arboricultural officers made the point forcefully that managing volunteers takes a considerable resource if it is to be done effectively and safely, and such resources are not currently in existence. Thus, in the context of building resilience, there currently seems to be only a limited prospect of community support, either for increasing the central budget for city trees or to participate in activities related to city trees such as tree health surveillance. However, it is possible that this position could change through targeted enabling and information programmes.

Citizen pressure groups can have a bearing on how arboricultural management could take place, a good example of which is the "Save the Tullos Deer Community[13]" in Aberdeen. Here, some city residents have strongly disputed the deer culling policy of the city council, which has been adopted in part for good silvicultural and arboricultural reasons. It is evident that this dispute remains unresolved but it is perceived as preventing arboricultural best practice from taking place. It highlights that some sections of society are very willing to challenge scientific and professional opinion regarding wildlife and tree management. Other city respondents mentioned some citizen pressure to plant only native species, though this was seen as a manageable issue.

7.3.6 The Nursery Trade: The importance of the nursery trade was raised by several respondents, as any requests for a diversity of suitable tree species for future Scottish conditions must be met by supply if progress in resilience building is to be made. One officer also questioned the genotypic variation of current nursery stock, suggesting that clonal stock would be more vulnerable to impacts as discussed above. In view of recent experience in connection with the introduction of ash die-back (*Hymenoscyphus fraxineus)*

[11] http://www.treecouncil.org.uk/Take-Part/Tree-Wardens
[12] For example, Glasgow Tree Lovers' Society (http://www.gtls33.org/)
[13] https://www.facebook.com/pages/Save-The-Tullos-Hill-Deer/152573201473640

into Britain through importation of plant material from mainland Europe, the need to purchase from local nurseries was stressed. Native woodland policy in Scotland is to recommend tree stock raised from local seed sources (Forestry Commission, 2006), though this hasn't been possible in practice (Cavers and Cottrell, 2015). Some nursery companies were praised for their support in helping practitioners choose 'the right tree for the right place' but it was implied that more could be done. Information on provenance and genotype are largely absent from nursery websites, and policies of growing from seed from UK (veteran) source trees[14] assume that these provenances are well suited to future climates.

8. Discussion

Scottish arboricultural officers appear to share very similar views and positions regarding the implications of climate change and of building resilience. Put simply, climate change has yet to make a significant impact on urban trees or their management. Instead, the combination of ageing tree populations coupled with a recent 'rain' of insect pests and microbial pathogens has brought home to arboricultural managers the need to respond by diversifying the demographic profile and species composition of their city trees. Such responses are also appropriate to meet the challenge of climate change, when this begins to impact on tree physiology and woodland ecology.

Nevertheless, building resilience will take some time, and the pertinent question is whether such responses are likely to be in advance of the projected impacts, or lag behind them. Certainly, recessionary budget cuts in recent years have prevented much proactivity, but it could be argued that it makes little sense to fell trees prematurely if they remain in good or satisfactory health and perform their primary function of helping to soften the urban landscape. Provided there are the means to replace ailing trees with species more suited to climates 'round the corner', and that might be resistant to likely pests and pathogens, this might be a proportionate response, and it is one that seems to be happening. Likewise, there is no 'one model fits all' solution as different cities will have different views and attitudes to species choice and it is probably more desirable to see evolution rather than revolution in this matter.

However, faced with statistics like those from Edinburgh where there are nearly 100,000 critical or dying trees (p. 6), it is necessary to ask if an adequate response has been made. Will future generations simply experience Scottish cities with far fewer trees in them, in spite of increased understanding of what real values they provide to urban societies? Some cities have published Tree and Woodland Strategies and Action Plans, but not all. And with

[14] e.g. https://www.barcham.co.uk/why-barcham/our-ethos/

resources and political leadership in comparatively short supply, it is not clear whether all the ambitions in these documents will be met. Worldwide, other cities are faced with similar challenges (for example Lyon, France; Melbourne, Australia; Toronto, Canada) and these appear to embrace more radical intervention to ensure a continuity in city tree populations for the future (see Ségur et al., 2011; City of Toronto, Parks, Forestry and Recreation, Urban Forestry, 2013; City of Melbourne, 2014;). It seems vital that city tree policies are interwoven with all other policy areas which have a bearing on tree survival and longevity. These include planning, green infrastructure, roads and communications, energy, flooding and water management, recreation, biodiversity and climate change. In this way, arboricultural officers would be better supported to meet the obvious challenge they have.

There was no clear evidence of the monitoring of adaptation mainly because in the context of climate change, this concept is largely absent from city tree and woodland strategies and was rarely used during interviews. The Asset Management systems in place, or being developed, in nearly all cities probably provide the most robust data from which to track adaptation but only if these systems can preserve tree information and prevent updates from rewriting over existing data. It would seem that some of these possess audit trail options[15] and are therefore capable of appropriate interrogation. However, work to develop appropriate adaptation indicators in this field is ongoing.

With a few exceptions, there was little enthusiasm for proactive novel research and/or the development of new decision support system (DSS) tools, though acceptance that the latter had some value if used correctly. Arboricultural officers appeared knowledgeable and experienced in the facets of their work related to resilience building, and drew from each other's experience in groups such as the Scottish Tree Officers Group (STOG) and in informal bilateral contact. Forest Research (FR) came in for special praise in respect of individual support given to arboricultural officers when contact was made with particular FR experts. There was a widespread interest in whether i-Tree ecosystem valuation techniques would prove useful in identifying the real importance of city and town trees to more senior city administrators. Further development of the i-Tree model to fit better with British conditions seems warranted. One city suggested that Forest Research had an important role in independently evaluating the results of i-Tree surveys in order to assess city tree sustainability and vulnerability and help refine policy. Other requests for supporting research focused on the genotypic variability of city trees, more information on species choice and on tree performance in trench systems. One city sought help to convert national statements on climate change to the city scale and to translate these into management

[15] e.g. http://www.ezytreev.com/

options that could be applied on the ground. There was a general request that relevant new findings are transmitted more effectively to those who can use them.

Of equal interest perhaps was the role that researchers might have in promoting the importance of urban trees in other fora. For example, it was suggested that scientific presentations should be made to the Chief Executives Conference (Convention of Scottish Local Authorities[16]), as well as to engineers and planners.

9. Conclusions

Modern valuation techniques such as i-Tree which embrace the ecosystem framework reveal that Scottish city trees have significant value for society. Yet the cities studied point to an ageing tree population under threat from pests, pathogens and people. There is a good understanding in city park, greenspace and environment departments of how to build resilience in city trees. Some actions such as diversifying tree species and finding commercial opportunity in urban woodland management are already taking place but progress has been slowed due to recent resource constraints. Such a position is not unique to Scotland, nor to the arboricultural sector. Nevertheless, there is considerable potential for city arboricultural officers to communicate effectively with their colleagues, with elected members and the wider community to raise awareness of the wide range of benefits that city trees can bring.

Acknowledgements

I thank all individuals named in Table 2 for the time they generously gave me during this research project.

[16] http://www.cosla.gov.uk/

References

Aberdeenshire Council (2005). *Forest and woodland strategy for Aberdeenshire and Aberdeen City*. http://www.aberdeenshire.gov.uk/natural/trees/forest_strategy05.pdf

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 Research Report, Stirling. http://greenspacescotland.org.uk/SharedFiles/Download.aspx?pageid=133&mid=129&fileid=95

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.

Cavers, S. and Cottrell, J.E. (2015). The basis of resilience in forest tree species and its use in adaptive forest management in Britain. *Forestry* **88**, 13-26.

City of Melbourne (2014). *Urban forest strategy. Making a great city greener 2012-2032*. http://www.melbourne.vic.gov.au/Sustainability/UrbanForest/Documents/Urban_Forest_Strategy.pdf

City of Toronto, Parks, Forestry and Recreation, Urban Forestry (2013). Sustaining & Expanding the Urban Forest: Toronto's Strategic Forest Management Plan. Toronto, Ontario. http://www1.toronto.ca/City%20Of%20Toronto/Parks%20Forestry%20&%20Recreation/Urban%20Forestry/Files/pdf/B/backgroundfile-55258.pdf

Davies, L., Kwiatkowski, L., Gaston, K.J., Beck, H., Brett, H., Batty, M., Scholes, L., Wade, R., Sheate, W.R., Sadler, J., Perino, G., Andrews, B., Kontoleon, A., Bateman, I. and Harris, J.A. (2011). Chapter 10: Urban. In: *The UK National Ecosystem Assessment Technical Report*. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Department of Energy & Climate Change (2012). *UK Bioenergy Strategy*. DECC, London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48337/5142-bioenergy-strategy-.pdf

Dundee City Council (2009). *Dundee tree and urban forestry policy*. http://www.dundeecity.gov.uk/sites/default/files/publications/urbanpolicy.pdf

Dundee City Council (2010). *Dundee TWIG. Trees & woods in greenspace action plan*. http://www.dundeecity.gov.uk/sites/default/files/publications/twigactplan.pdf

Edinburgh City Council (2014). *Trees in the city. Trees and woodlands action plan, January 2014*. http://www.edinburgh.gov.uk/download/downloads/id/1540/trees_in_the_city_action_plan

Emmanuel, R. (2013). *Green Infrastructure for overheating adaptation in Glasgow*. Final Report to Glasgow Clyde Valley Green Network Partnership (GCVGNP). http://www.gcvgreennetwork.gov.uk/212-green-infrastructure-for-overheating-adaptation-in-glasgow/file

Emmanuel, R. and Krüger, E. (2012). Urban heat island and its impact on climate change resilience in a shrinking city: The case of Glasgow, UK. *Building and Environment* **53**, 137–149.

Forest Research (2010). *Benefits of green infrastructure*. Report by Forest Research. Forest Research, Farnham. http://www.forestry.gov.uk/pdf/urgp_benefits_of_green_infrastructure.pdf/$FILE/urgp_benefits_of_green_infrastructure.pdf

Forest Research (2013). *Climate change adaptation in the Glasgow and Clyde Valley: opportunity mapping for woodland creation to reduce flood risk*. Report prepared for the GCV Green Network Partnership. http://www.gcvgreennetwork.gov.uk/211-climate-change-adaptation-in-the-glasgow-and-clyde-valley-opportunity-mapping-for-woodland-creation-to-reduce-flood-risk/file

Forestry Commission (2006). *Seed sources for planting native trees and shrubs in Scotland*. Forestry Commission Scotland Guidance Note, 10 pp. http://scotland.forestry.gov.uk/images/corporate/pdf/seedsourcefcfc151.pdf

Forestry Commission Scotland (2011). *Woods in and around Scotland. The story so far*. Forestry Commission, Edinburgh. http://scotland.forestry.gov.uk/images/corporate/pdf/WIATProgressReportstorysofar.pdf

Forestry Commission Scotland (2013). *Climate Change Programme*. Forestry Commission, Edinburgh. http://scotland.forestry.gov.uk/images/corporate/pdf/climate-change-programme.pdf

Glasgow City Council (2013). *Design Guide. New Residential Areas*. http://www.glasgow.gov.uk/CHttpHandler.ashx?id=15298&p=0

Greenspace Scotland (2009). *State of Scotland's Greenspace 2009*. Greenspace Scotland, Stirling. http://www.greenspacescotland.org.uk/SharedFiles/Download.aspx?pageid=133&mid=129&fileid=278

Heritage Lottery Fund (2014). *State of UK public parks 2014*. Research report to Heritage Lottery Fund, June 2014. http://www.hlf.org.uk/file/10325/download?token=_CydIHinzYaJyX9xVmRtFv0qLEhimcImH2Xw3TK8yU4

Hutchings, T., Lawrence, V. and Brunt, A. (2012). *Estimating the ecosystem services value of Edinburgh's trees*. Forest Research, Farnham.

http://www.edinburgh.gov.uk/download/downloads/id/1540/trees_in_the_city_action_plan

Irving, D., Esposito, R., Finkle, M., Corbett, A. and Hislop, M. (2014). *Central Glasgow: retrofitting green infrastructure – a case study*. Greenspace Scotland. http://greenspacescotland.org.uk/SharedFiles/Download.aspx?pageid=133&mid=129&fileid=464

Mackinnon, K.A.H. (2013). *Measuring Edinburgh's Surface Urban Heat Island*. Unpublished M.Sc. thesis, University of Edinburgh.

Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being.: synthesis*. Island Press, Washington D.C.

National Tree Safety Group (2011). Common sense risk management of trees. Landowner summary of guidance on trees and public safety in the UK for estates and smallholdings. Forestry Commission, Edinburgh. http://www.forestry.gov.uk/safetreemanagement

O'Neill, A., Trail, A., Picking, A., Nevin, M. and Holmes, N. (2010). *Arboricultural Arisings Scotland Study*. Report to the Forestry Commission Scotland. International Synergies Ltd. http://www.biomassenergycentre.org.uk/pls/portal/url/ITEM/00708E0BF8A980B4E05014AC080462D2

Quine, C.P., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A.J. and Valatin, G. (2011). *Chapter 8: Woodlands*. UK National Ecosystems Assessment Technical Report. UNEP-WCMC, Cambridge. 53 pp. http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=EuaMBUTBZIU%3D&tabid=82

Ray, D. (2008). *Impacts of climate change on forestry in Scotland – a synopsis of spatial modelling research*. Forestry Commission Research Note FCRN101. Forestry Commission, Edinburgh. http://www.forestry.gov.uk/pdf/FCRN101.pdf/$file/FCRN101.pdf

Rockefeller Foundation (2009). *Building Climate Change Resilience*. http://acccrn.net/sites/default/files/publication/attach/10_RF_WhitePaper_Resilience.pdf.

Royal Society (2014). *Resilience to extreme weather*. Royal Society Science Policy Centre report 02/14, London. https://royalsociety.org/~/media/policy/projects/resilience-climate-change/resilience-full-report.pdf

Rumble, H., Rogers, K., Doick, K. and Hutchings, T. (2015). Valuing urban trees in Glasgow. Assessing the Ecosystem Services of Glasgow's Urban Forest: A Technical Report. Unpublished Report, Forest Research, Farnham.

Scottish Executive (2002). *Guide to native trees and shrubs. A Designer's Guide to their Selection, Procurement & Use in Road Landscape*. http://www.aberdeenshire.gov.uk/planning/devservices/biodiversity/Scotland%27s%20Nati

ve%20Trees%20and%20Shrubs%20A%20Designer%27s%20Guide%20to%20their%20Selection,%20Procurement%20and%20Use%20in%20Road%20Landscaping.pdf

Scottish Government (2014a). *Scottish Planning Policy*. Scottish Government, Edinburgh. http://www.gov.scot/Resource/0045/00453827.pdf

Scottish Government (2014b). *Climate Ready Scotland: Scottish Climate Change Adaptation Programme*. Scottish Government, Edinburgh. www.gov.scot/Resource/0045/00451392.pdf

Scottish Natural Heritage (SNH) (2012). *Climate change and nature of Scotland*. SNH, Edinburgh. http://www.snh.org.uk/pdfs/publications/corporate/Climatechangenaturescotland.pdf

Ségur, F., Benassi, A., Noyel, A., Neyret, J. and Duprey, F. (2011). *La Charte de l'arbre*. Grand Lyon. http://www.grandlyon.com/fileadmin/user_upload/media/pdf/environnement/arbres/20111214_gl_chartearbre.pdf

Stirling Council (2012). *Open Space Strategy 2012-17*. http://www.stirling.gov.uk/__documents/temporary-uploads/economy,-planning-_and_-regulation/openspace-strategy/open-space-strategy-2012-17.pdf

Stirling & Clackmannanshire Councils (2014). Stirling & Clackmannanshire Forestry and Woodland Strategy.

Thomas, K. and Geller, L. (2013). *Urban Forestry. Towards an ecosystem services research agenda. A workshop summary*. National Academies Press, Washington. http://download.nap.edu/cart/download.cgi?&record_id=18370

Tubby, K.V. and Webber, J.F. (2010). Pests and diseases threatening urban trees under a changing climate. *Forestry* **83**, 451-459. http://forestry.oxfordjournals.org/content/83/4/451.full.pdf+html

UK National Ecosystem Assessment (2011). *The UK National Ecosystem Assessment Technical Report*. UNEP-WCMC, Cambridge.

Van der Jagt, A. and Lawrence, A. (2015). *Trees and Woods in Scottish Towns: The role of Local Authorities*. Forest Research, Edinburgh. http://www.forestry.gov.uk/pdf/FR_vanderJagt_Lawrence_TWIST_2015.pdf/$FILE/FR_vanderJagt_Lawrence_TWIST_2015.pdf