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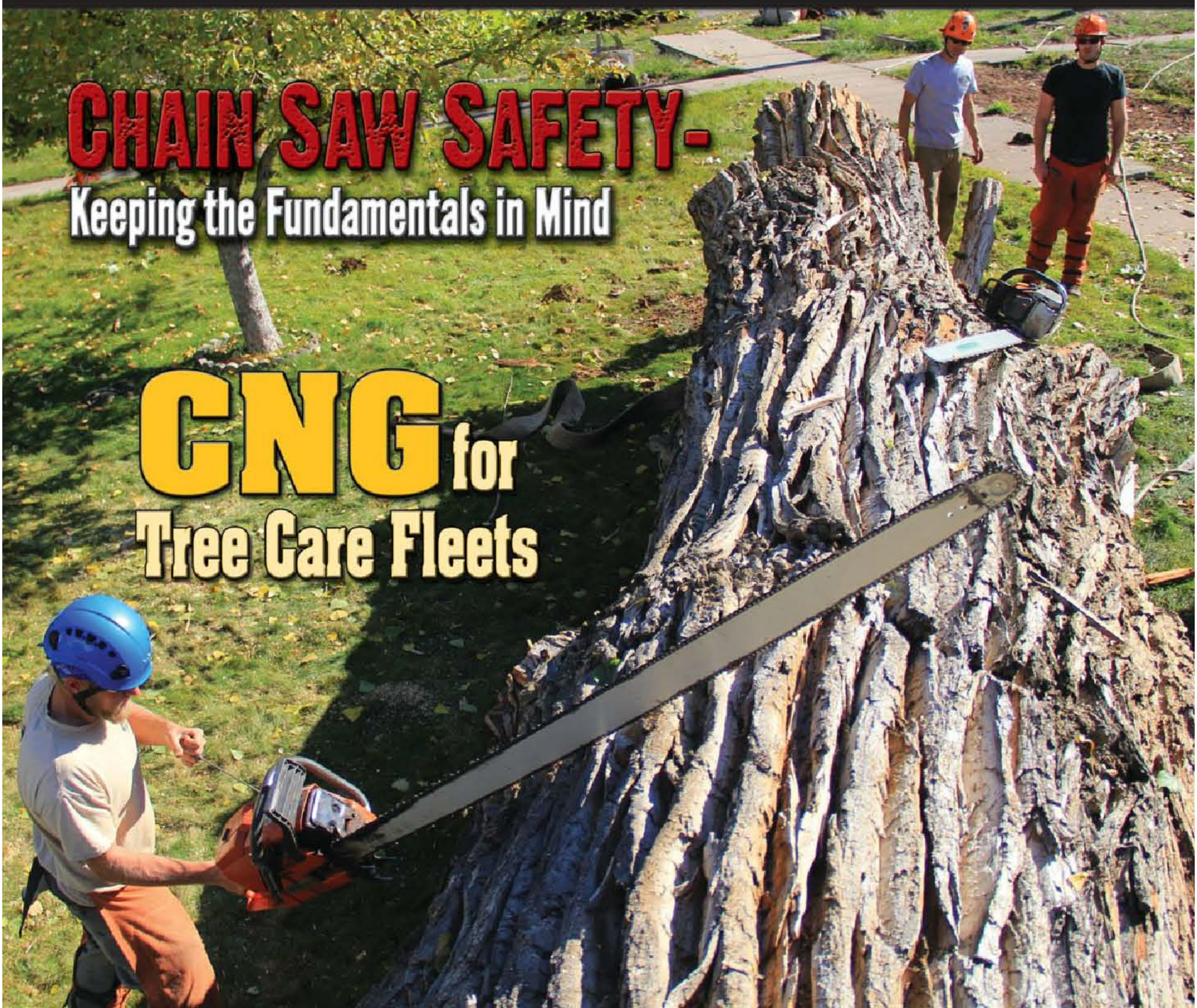

Sustainability

DETERMINING TREE GROWTH for CLIMATE, HEALTH and WEALTH

This poor choice for an urban tree in Chapel Hill, North Carolina, has become a hazzard to pedestrians. Photo by Michael Sauers@flickr.com

Saving urban trees through growth prediction

By Kenton Rogers

The multiple benefits of urban trees, woodlands and green spaces are well documented. Trees filter pollutants, reduce the urban heat island effect, provide aesthetic interest and can even reduce crime or encourage greater consumer spending. These benefits are even more pronounced in urban areas, helping to make towns and cities better places to live.

Despite the obvious benefits, trees in urban areas are often those under the greatest pressure, facing issues such as increased summer temperatures or pollution levels, compacted soils, salt contamination, development and vandalism to name a few. Consequently, urban tree numbers have been steadily declining.

So how can we reverse this trend of urban tree suffering? The answer lies in growth prediction. By predicting growth of various tree species, researchers and urban forest managers can model cost benefit analysis, investigate alternative management scenarios and choose best management practices for increasing the benefits from trees, all of which create more sustainable urban forests. Selecting, locating and managing trees to provide ecosystem services is becoming increasingly important, and the science of determining urban tree growth is fundamental to quantify these services.

Measuring tree growth

In forestry disciplines, tree growth has been measured for centuries and the relationships between site conditions and management are better understood. Yield tables and production forecasts are avail-

Table 1: Simple linear growth rates (with standard deviation in brackets)

	Average Tree DBH increment (cm) per year		Average Tree Height increment (meters) per year		Average Tree Canopy (m) increment per year	
MAX	0.556		1.667		3.75	
MIN	0.044		0.372		0.082	
All Average	0.3		0.75		0.84	
Open Grown Tree Average	0.394		1.455		2.541	
Others Average	0.255		0.645		0.465	
Oak	0.228	(0.08)	0.601	(0.25)	0.588	(0.43)
Ash	0.4	(0.08)	0.926	(0.33)	0.863	(1.15)
Syc	0.341	(0.08)	0.84	(0.33)	0.931	(1.05)
Beech	0.22	(0.17)	0.643	(0.50)	0.635	(0.97)

able for a variety of different species, sites and management prescriptions in many different countries. Unfortunately, the equations and empirical tables developed for plantation forestry are not directly relevant to open-grown urban trees because they are based on even-aged, "pure forests." Relying on equations developed in traditional forests could lead to huge variances in the growth estimates when applied to urban trees and woodlands.

Existing urban forest growth models revealed that little work has been done in this area. The majority of existing studies are based on public tree inventories where trees of different ages are measured to establish the relationships between age, stem diameter and other growth variables such as crown height or width. As the trees in the studies are only measured at one point in time, public records are essential in providing the age of the trees studied.

Finding a new model

As part of our recent study in the United Kingdom, "Determining Tree Growth in the Urban Forest," we reviewed these methods and, fortunately, there was an alternative. A. E. Douglas pioneered the science of dendrochronology in the early part of the last century, studying both conifer and hardwood trees from sites in North America and Europe (although he is most well known for his work developing a chronology from the giant sequoia, *Sequoiadendron gigantium*). He demonstrated that the widths of the annual rings correlated with climatic variations and that this pattern also corresponded with patterns of narrow or wide annual rings from different trees in the same area. This is because trees respond to climatic variations such as precipitation, temperature and available sunlight and are excellent at capturing short-frequency variability. It was, therefore, an ideal method to use where no planting records exist.

Study of Torbay, United Kingdom

Working in the Torbay area of Devon, United Kingdom, where there were no planting records available, we aimed to use this method in determining tree growth of four different species (oak, *Quercus robur*; ash, *Fraxinus excelsior*; sycamore, *Acer pseudoplatanus*; and beech, *Fagus sylvatica*) for the last 100 years. In all, 104 core samples (two per tree) were collected from the area during the winter of 2011/12. As well as determining growth rates, growth could also be compared against past meteorological data to establish if there was any significant effect on tree growth.

Data on the ring measurements for each sample were recorded using TSAP-Win software, a platform for tree ring analyses. The two cores for each tree were compared in order to remove any false rings and to insert any missing rings.[1] This process is referred to as cross dating and can be done by visual or statistical methods. A visual approach is preferred for the initial assessment and before any time series analysis is undertaken. Once visually cross dated (and provided the correlation was significant), the data from the two cores were averaged to provide a mean growth increment for each tree. Averages were then prepared for

Table 2: Event years

Year	Average All Beech (Ring widths in 1/1000 mm)	Average All Ash	Average All Oak	Average All Sycamore	Average Yearly Rainfall mm	Sun hrs/ 24hr Year	Temp Year	Event Notes
1933	1,625	5,365	2,500	3,511	1.94	5.30	10.95	Notably warm summer: one of the top 7 or so of the century. Regarded as from June to September.
1937	1,932	2,560	1,935	2,656	2.88	4.53	11	One of the wettest Februarys across England & Wales (using the England Wales Precipitation (EWP) series.
1963	1,474	2,036	1,948	2,539	2.52	4.16	9.1	Mt. Agung (Bali, Indonesia/East Indies) erupted Feb. 18. Gas & volcanic dust reached more than 10 km above the crater, high enough to reach the stratosphere. Atmospheric effects, including dramatically colored sunsets & halos around the sun, encircled the earth within a few weeks; a decrease in light was measured from distant stars, at a maximum between Aug. to Nov. 1963, lasting to some extent until mid-1964. Stratospheric temps rose as much as 6 degrees C, and the average world near-surface temperature dropped 0.4 C for 3 years after the eruptions.
1966	2,380	3,441	2,722	3,933	2.94	4.88	11.26	One of wettest Febs. across England & Wales (using the EWP series). Rainfall totals over 200% of avg.
1976	1,272	2,301	1,684	2,212	2.18	5.31	11.24	1975/1976 (May to April): For the EWR series (since 1727), the 12 month period May 75 to Apr 76 was (at the time) the driest. 1975/1976 (two-year drought): The drought of 1975/76 was severe over most of the British Isles, also exceptionally persistent. It produced the highest values for a drought index for southeast England in 300 years.
1989	2,367	4,321	2,760	2,944	2.5	5.05	12.14	Sunniest year in central London on record, which began in 1929. 1915hr recorded (against 1762hr in 1976). 2. Over a large part of the United Kingdom, one of the warmest & sunniest in the modern (reliable) record. [see also 1959, 1995 & 2003].
1992	3,210	3,883	2,428	3,842	2.32	4.60	11.41	Warmest May of 20th century over much of Britain, & in top-5 warmest Mays in the entire CET record (others were from 18th &19th century, so some doubt).
1996	1,949	3,478	2,195	2,744	2.54	4.95	10.71	Driest year in the Heathrow record (started 1947). Coldst year since the mid 1980s as well. A very dry year in the EWP series: 682.2 mm/5th driestin that series (as at 1999).
1997	2,680	4,034	2,476	3,985	2.38	5.11	12.01	30 month precipitation totals up to Sept. 1997 were lowest on record in England & Wales, with estimated return periods exceeding 200 years in many districts.
AVG*	2,099	3,491	2,294	3,152	2.47	4.88	11.09	
				Min*	1.10	2.96	8.81	
				Max*	3.17	6.13	12.45	

All Notes Sourced from Booty(2012)

*(from all series years – not just those listed)

each species and these correlated well together, both statistically and visually.

The study found that in the urban environment of Torbay, overall growth was greatest in ash, followed by sycamore, oak and, finally, beech (Table 1). In general terms, it was found that growth in Torbay's trees is greater than that observed in the Eastern European climate zone, but are much less than the general base rates for various U.S. studies. This was reassuring as it is what one might expect.

When growth was compared against the meteorological data, significant relationships were found for the beech, ash and oak, but not for the sycamore. This could mean that this species is either not sensitive to the weather conditions recorded or that it is not entirely suitable for dendroclimatology research. Indeed, we found that the growth rings in the sycamore samples had the greatest variability and were the most difficult to interpret. No significant correlation with the meteorological data was recorded and this may limit its usefulness as a tree for establishing patterns in tree growth for other studies.

One of the most interesting aspects of this work however was to visually interpret the annual ring growth marker years for poor and good growth years and to see if there were any corresponding meteorological events (Table 2). Results were interesting, for example: 1976 was a key event year, being a severe drought. Poor growth rates were also observed in 1896/7 and 1917, but there was no local data available. Anecdotal evidence suggests however that the winter of 1916 was one of the wettest of the century.

UK-wide surveys to inform urban tree management

Following on from this study, Forest Research UK will be rolling out a similar urban trees survey across five UK cities: Cardiff, Birmingham, Peterborough, Glasgow and Edinburgh. This survey involves taking tree cores from four species of open grown trees: ash, sycamore, oak and silver birch, *Betula pendula*. It is hoped that their wide geographical spread across the UK will determine any variability in their growth patterns due to climate, thereby increasing our understanding of climatic issues faced by the urban forest. It is likely that in the future such methods will be used for modeling tree growth against different climate scenarios to enable better urban tree management, species selection and a more sustainable future for urban trees.

Note

1. Sometimes, trees also produce growth patterns that appear to be annual rings but are, in fact, "false rings" or "intra annual growth." This can be caused by drought or other environmental stresses triggering cell wall thickening in the growing season. Conversely, in some years discernible growth rings may not form at all ("missing" or locally absent rings). Locally absent rings cannot be reliably detected in single core samples, and this is why two cores are compared and an average taken for each tree.

Kenton Rogers, is a member of the Institute of Chartered Foresters, a forestry consultant and founder of Treeconomics Ltd., a firm specializing in valuing ecosystem services – the economic, environmental and financial value of trees, forests and green infrastructure, in Polegate, East Sussex, England. He will be speaking on this same subject, how new methods of determining tree growth can create a more sustainable future for city trees, at the Institute of Chartered Foresters conference, "Trees, People and the Built Environment II," April 2-3, 2014, at Birmingham University, in Birmingham, England. The Institute of Chartered Foresters is the professional body representing foresters and arborists in the United Kingdom. For more information or to registration for the conference, visit www.charteredforesters.org/conference 2014.

The study referenced in the article, "Determining Tree Growth in the Urban Forest," can be found at www.treeconomics.co.uk/uk-treeconomics-pilot.