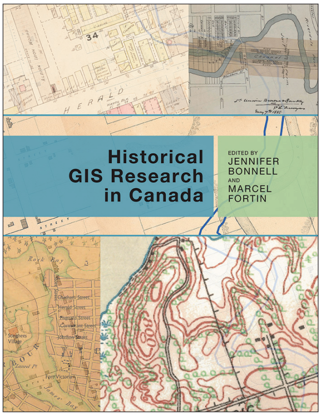

HISTORICAL GIS RESEARCH IN CANADA
Edited by Jennifer Bonnell and Marcel Fortin

ISBN 978-1-55238-756-6

Acknowledgement: *We acknowledge the wording around open access used by Australian publisher,* **re.press**, *and thank them for giving us permission to adapt their wording to our policy* http://www.re-press.org

6

Mapping Ottawa's Urban Forest, 1928–2005

Joanna Dean and Jon Pasher

Like many HGIS projects, this research began with a question that could not be answered with traditional historical sources. Municipal records showed dramatic shifts in attitudes to city trees in the mid-twentieth century. We wanted to know whether these cultural shifts reflected changes in the urban forest itself.[1] Were there too many trees in the 1920s, as critics charged? Were there too few in the 1960s, as environmentalists claimed? And how many trees are too many, anyway? The question was of more than academic interest. Urban foresters have established that trees provide significant health and climate benefits by cleaning and cooling city air. Trees can live for decades, and historical analysis can contribute to our understanding of forest growth and improve management in the future.

Our pilot project assessed the use of historical aerial photographs to measure canopy cover on selected neighbourhoods in Ottawa. The techniques for measuring forest canopy cover from aerial photographs and satellite images are well tested, but little historical analysis has been done, and the use of historical aerial photographs complicated the project in a variety of ways.[2] We found that it was possible to measure canopy cover within a reasonable margin of error. It appears that the critics may have been right, that tree cover was dense in central parts of the city in the early twentieth century and that it subsequently declined. It appears that the environmentalists were also right to worry about trees in the 1960s, when the inner-city decline was matched by the deforestation in early suburbs like Alta Vista.

What was interesting, however, was that geospatial analysis took the research beyond the original question: not only could we draw connections between canopy cover and shifts in popular opinion, but we could also correlate canopy cover to social indices such as class, income, or race. Inner-city neighbourhoods were subjected to close scrutiny for urban renewal in the postwar period, and a wealth of statistics are available. Our pilot project had not been designed with this analysis in mind, but even so the correlation of income and canopy cover is clear. The statistics allow us, following Nik Heynen in the United States, to insert the urban forest into an environmental justice framework as an environmental benefit that is socially produced and unevenly distributed.[3]

The project also offered an opportunity to move beyond statistics. Our methodology created maps of canopy cover that can be read visually and stacked in a dynamic time series. This has the potential to alter our perception of the urban forest. Trees appear to humans to be static entities, and their growth is only recognized retrospectively: it is a common trope of memoir writers to observe with surprise that a childhood tree has grown. The dynamic changes of canopy cover visible in a time series reminds us that forests are living agential communities that move and respond to changes in the built environment.

While our own work and experiences are focussed on urban forests, the methods and issues are applicable to other HGIS applications. The observations arise from the different perspectives of project team members. Jon Pasher, who was completing his doctorate in Geography at the time of the project, focussed on the methods, development, and accuracy of the statistics. Joanna Dean, a historian of the urban forest, with very little experience in HGIS, focussed on the applicability of the method for environmental history. The project described here was a pilot project, funded with a small SSHRC grant, and possible only because of the generosity of colleagues in the Geomatics and Landscape Ecology Laboratory at Carleton. We analyzed only five carefully selected areas, and, as in any good pilot project, we learned from our mistakes. We offer the following observations as "lessons learned," intended to be useful to others interested in incorporating historical air photos into their HGIS research.

CONTEXT

Urban forests have been the subject of much recent analysis in Europe and North America. The recognition of the environmental benefits or services provided by city trees led to a growing demand for the quantification and monetization of these benefits, and the developing science has provided the context for our research.[4] The term "urban forest" was coined by Erik Jorgensen, at the University of Toronto Faculty of Forestry, and has been widely adopted. The term is generally understood to include all urban trees: the street trees that line roads, as well as single trees and groups of trees in gardens, yards, cemeteries, parks, and woodlands. Although the urban tree is normally distinguished from shrubs and other vegetation by its trunk and crown (the urban tree is defined as "a woody perennial plant growing in towns and cities, typically having a single stem or trunk – and usually a distinct crown – growing to a considerable height, and bearing lateral branches at some height from the ground,"[5]) most observers include shrubs within an urban forest. For those involved in canopy cover analysis of aerial photographs and remote sensing, it is often difficult to distinguish between trees and shrubs, and, as the ecoservice benefits are similar, the inclusion of shrubs makes sense methodologically. Ecologists sensitive to the interrelationships between plants and animals tend to think more broadly, and the term urban forest is sometimes extended to include grass, and even the related biota in an urban ecosystem.[6]

Urban foresters have established that urban trees provide a wide array of ecosystem services: they moderate air temperature, attenuate storm water flooding, mitigate urban heat island effects, and reduce noise and air pollution. Trees have been shown to have a measurable impact on urban levels of particulate matter, ozone, sulphur dioxide, nitrogen dioxide, and ozone. Woodlands increase urban biodiversity by providing semi-natural habitats to a wide variety of species, and at a broader scale urban trees contribute to carbon sequestration and storage.[7] They also provide social benefits: not only do they make a city aesthetically pleasing, (and raise real estate values), but they have measurable impact on residents' health and sense of wellbeing. Trees growing within sight of a hospital room have been shown to improve recovery rates of patients.[8] At the same time, urban trees also provide disservices: they produce allergenic pollen, volatile organic compounds (contributing to smog), and green waste. The costs and inconveniences of tree management can be high in urban areas, especially during storms, when they do significant damage to infrastructure. Not all city residents value the aesthetics of a treed urban landscape.[9] But the consensus is that the services outweigh the disservices, or have the potential to do so if well managed, and so the emphasis in the literature is on improved understanding and management of urban trees.[10]

Because of the focus on these ecosystem services, and the interest in assigning monetary values, many urban forest studies adopt quantitative methods: field surveys for smaller areas and GIS, aerial photography and remote sensing for larger areas.[11] The science has developed with advances in remote sensing and spatial analysis. It is often possible to acquire high-resolution satellite images with a spatial resolution of 60 cm and as well many municipalities have acquired low-altitude aerial photographs, which, although often intended for other purposes, can prove very useful for identifying canopy cover. One recent study demonstrated the inequitable distribution of greenspace in Montreal by extracting vegetation indicators from high-resolution satellite images, indicating the proportion of city blocks, streets, alleys, and backyards covered by total vegetation and trees/shrubs. These data were correlated to census data at the level of the dissemination area (400–700 people, roughly a city block in Montreal) to show environmental inequities.[12] One of the authors of this chapter, Jon Pasher, is currently engaged in a national-scale analysis of carbon sequestration within the urban areas of Canada. As a pilot project at Environment Canada, high-resolution imagery is being used to assess urban canopy cover to improve on previous estimates of the contribution to Canada's urban area carbon budget calculations.

Historical studies are limited by the available data: aerial photographs from the mid-twentieth century do not permit this kind of close digital analysis. Historical studies are worth attempting, however, because of the longevity of trees. Unlike most vegetation, trees survive for decades, even in some cases centuries. In a young city like Ottawa, trees can be older than the city itself. Dendrochronology showed that a bur oak, recently cut down for infill housing, was 154 years old, the same age as the City of Ottawa, ninety years older than the house it shaded and at least a hundred years older than the man who felled it.[13] Trees also take many years to die. Analysis of a group of bur oaks in Winnipeg showed that they had been in decline for decades because of changes in water table levels caused by residential construction in the 1940s.[14] In another project, core analysis of urban Norway maples led ecologists to conclude that the trees had been in decline for twenty years. They speculated the decline was related to a combination of drought and sidewalk renovation and noted: "serious symptoms of deterioration in the crown may not occur for many years after the onset of decline."[15] If the purpose of urban forest analysis is to improve management, then historical studies capable of assessing arboreal growth and decline over a number of decades will be essential.

METHODOLOGY

Historical air photos were obtained from the Canadian National Air Photo Library. Each photo was scanned and georeferenced to real-world geographic coordinates within a GIS environment by collecting matching tie-points on both the older photos as well as more recent digital air photos, which were already georeferenced. While the scales of the photos differed greatly, the pixel size, or "spatial resolution" was standardized for all the photos in a time series in order to standardize the level of detail at which the interpreter would outline the canopy. A minimum bounding study area was set in a neighbourhood that included as large an area as possible but at the same time as many historical photos as possible. Within these reduced study areas, tree cover was manually interpreted and digitized in a GIS environment. The methodology resulted in maps of canopy cover that can be interpreted visually. The resultant GIS layers provided a per cent canopy coverage within each study area over time, by taking the aerial estimates of digitized canopy cover as a percentage of the total area of the neighbourhood being analyzed.

This methodology was adopted from landscape ecology and represents a departure from the dot-grid methodology used for most urban forest analysis. Dot grid, used for political ecology by Nik Heynen and by urban forester David Nowak, has developed from the pre-digital era, when a clear dot grid was placed over an aerial photograph, and the number of dots lying on forest canopy were counted. (See Figure 6.1B.) The results provide an average measure of canopy cover for an entire city but do not provide precise measures of individual neighbourhoods and streets unless intensive sampling is done in small areas.

Our methodology relied on the painstaking manual digitization of the canopy cover of each and every tree, but the results are dramatic. Patterns of canopy cover change can be read visually and can be read at the street-by-street, and even tree-by-tree level. While point based sampling might be faster to carry out, it does not allow for close analysis of changing spatial

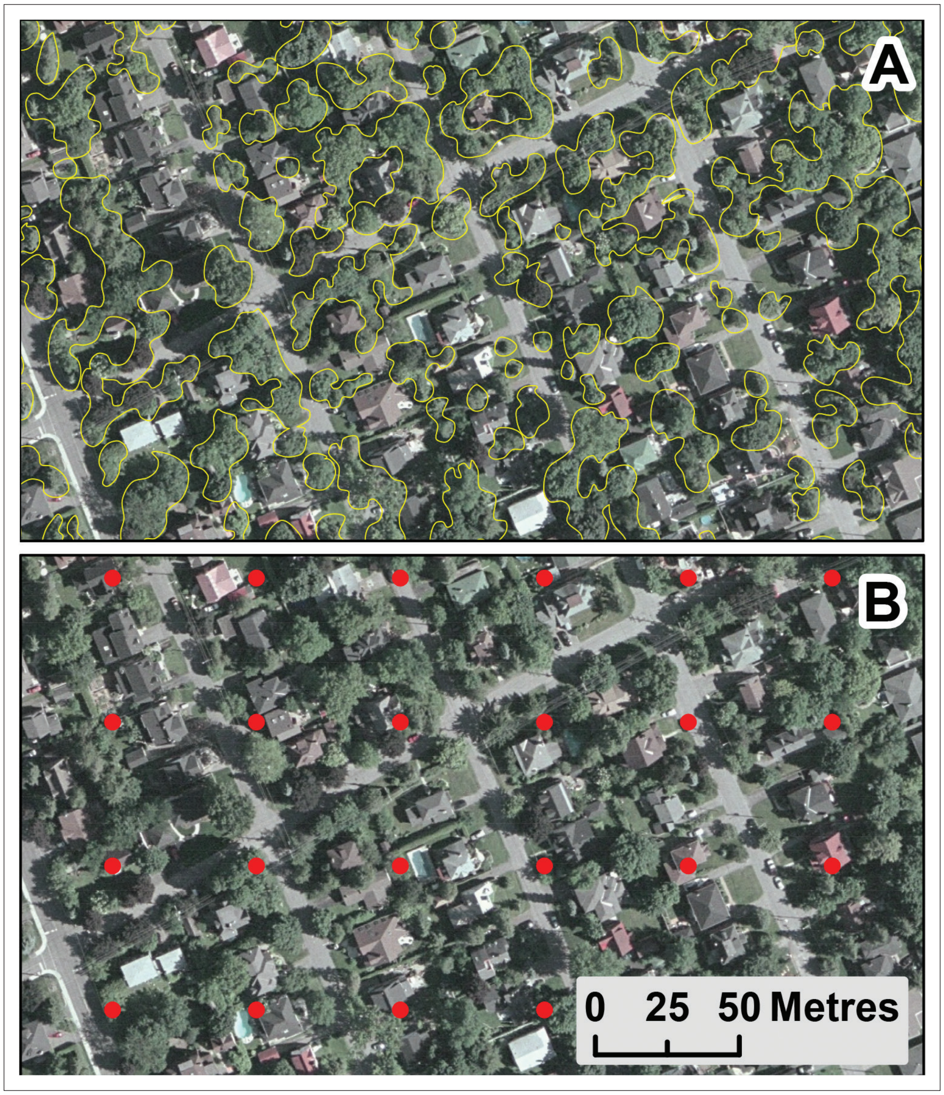

Fig. 6.1. Commonly used canopy cover analysis methods including (A) manual digitizing of canopy cover and (B) point-based sampling.

patterns. (Figure 6.1 demonstrates the difference between the two most common methods.) A second benefit is that individuals with no expertise in geospatial analysis can easily grasp the meaning of the maps. This is important for communicating results with other historians and sharing them with community groups.

We encountered interpretation difficulties that can be classified into three main categories: 1) data availability, 2) data quality, and 3) photo attributes. The availability of historical aerial photographs limits the spatial coverage and depth of analysis that can be performed. In the early years, the flight paths along which photos were taken were sporadic both in terms of spatial coverage and temporal coverage, limiting the neighbourhoods available for analysis, as well as the number of photos available through time for the different neighbourhoods. In many cases, we were able to go back to 1946 photos (and occasionally as far back as 1928); however, regular time intervals were not always

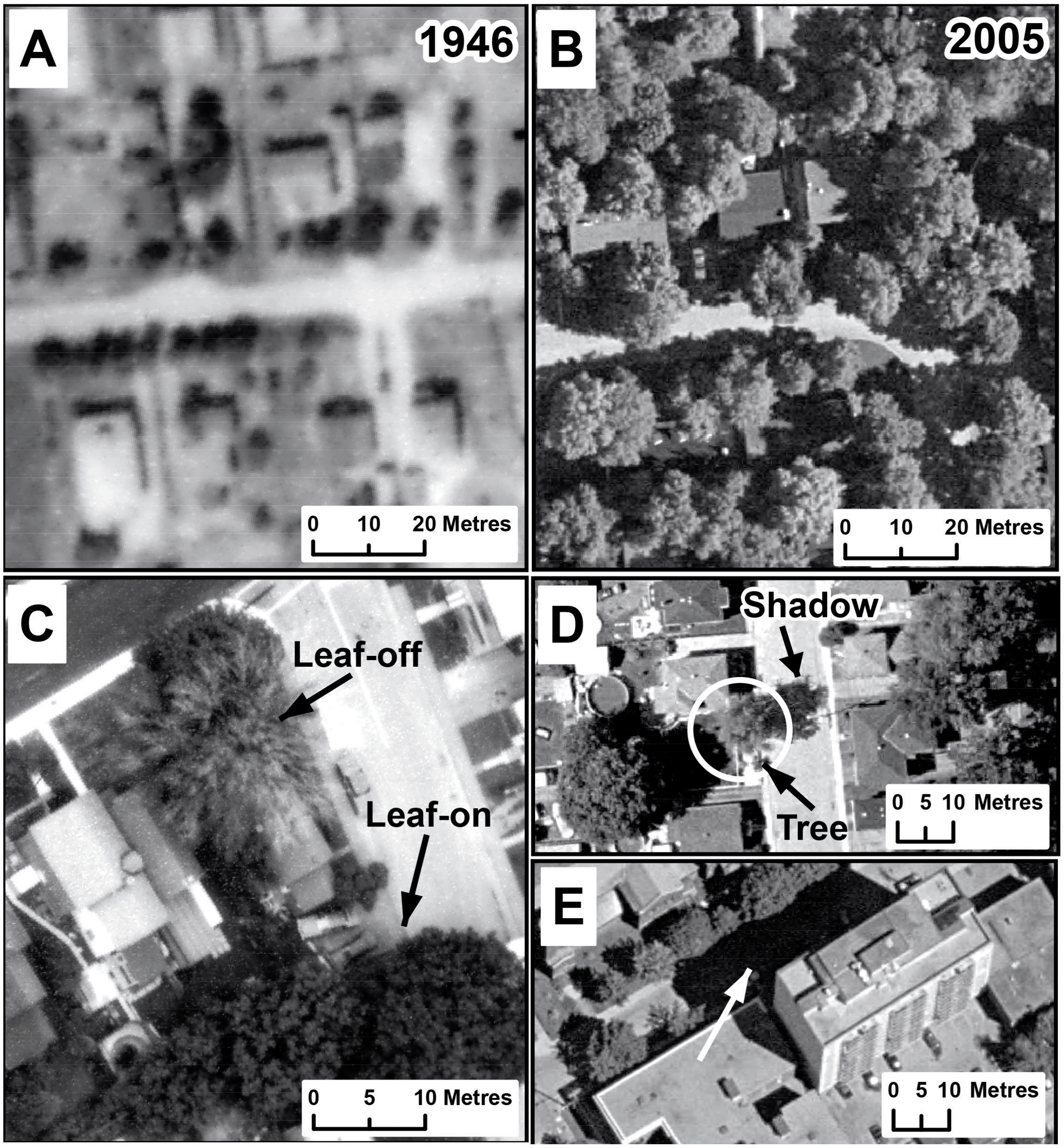

Fig. 6.2. Close-up examples of air photos illustrating some of the issues encountered when digitizing and analyzing. (A) Poor-quality photo (taken in 1946) as a result of technology as well as aircraft height compared with a 2005 photo (B) taken at a lower height using new technology. (C) A comparison between leaf-on and leaf-off conditions demonstrating the difficulty in delineating the crowns of the trees. (D) A large tree-shadow as a result of the low sun angle at the time the photo was taken, demonstrating interpretation difficulties. (E) Shadows created by an apartment building, potentially hiding trees lining the street behind.

Fig. 6.3. Guiges and King Edward Avenue, 1938. Street trees, many of them silver maples, shaded Lowertown in the 1930s. This photograph is from a series of streetscapes used by landscape architect Jacques Gréber that emphasize the beauty of the trees. (Guiges and King Edward [west], Library and Archives Canada/ Department of Public Works fonds/ e010869284.)

possible. In one case, although we had photos from 1946, 1952, and 1956, there were no photos available again until 1985. Such gaps in time have a significant impact on results, especially in such a dynamic environment. Spatial gaps were also problematic. The Canadian government began to gather data for urban "census tracts" in the postwar period, but our study areas rarely matched these tracts, and so the correlations with social indices are not as exact as we might have wished.

Even when photos were available over a specific area, we encountered problems with different acquisition scales (i.e., the aircraft was at a different height during the acquisition, or a different camera lens was used), which resulted in differing levels of image resolution and clarity. (See Figs. 6.2A and 6.2B) While older photos were interpretable by an expert, the results were not as accurate.

The attributes of the photos related to the seasonality and time of day of the acquisitions also caused variability. We sometimes were forced to rely upon photos that were taken in the spring when not all of the tree leaves had opened up and in the fall when some of the leaves had already fallen off. Figure 6.2C demonstrates this issue, with crown delineation hindered when the leaves were not present. Further, as with any work using air photos in an urban environment, shadows are often present. Figure 6.2D provides an example of a large tree shadow cast across the road. Interpretation of these shadows was particularly difficult in older air photos that were only available in greyscale (as opposed to true colour, which is available in more recent photos). Figure 6.2E demonstrates the fact that buildings cast shadows, preventing interpreters from seeing and therefore mapping trees lining the street. Issues of shadows are magnified by photos taken with a low sun angle as well as the presence of taller buildings. Despite these difficulties, we concluded that, while the statistics calculated were by no means exact, the relative measures calculated tell interesting and useful stories about changes over time and provide additional information unobtainable without such techniques.

LOWERTOWN, 1946–2005

Analysis of Ottawa's oldest neighbourhood, Lowertown, reveals the impact of natural and social forces on tree canopy cover. Lowertown was built upon a cedar swamp, and it was initially occupied by the Irish and French Canadian labourers employed in building the Rideau Canal. In the 1940s, when our analysis starts, it was a cohesive francophone working class neighbourhood, distinguished by a landscaped federal avenue, King Edward Avenue, leading from the Governor General's residence, and the bustling commerce of the Byward Market. Street-level photographs taken in the 1930s show a dense canopy cover with tree trunks crowding narrow residential streets.[16] (See Fig. 6.3.) Today there are a few remaining massive street trees, some new street tree plantings, and large spreading trees to the rear of the houses. GIS analysis of one small section of Lowertown shows that the canopy cover was 32 per cent in 1946, dropped to 22 per cent a decade later, and further to 10 per cent in 1966 and 1976. It has only risen to 15 per cent in recent years. (Figure 6.4 shows a time series of photos from 1946 to 2005, and Fig. 6.5 shows mapped canopy cover changes from 1946 to 2005).

The study area for Lowertown was small, but this example shows the importance of occasionally working at an even lower scale, on a street-by-street basis. King Edward Avenue is visible on the right in Figs. 6.4 and 6.5: it was landscaped by the Ottawa Improvement Commission in the early twentieth century with a wide central boulevard of American elm trees. The trees grew magnificently (they were planted over a bywash from the Rideau Canal) and by the 1940s provided deep shade. This avenue was selected by urban planner Jacques Gréber to illustrate the beauties of Ottawa trees; a photograph of King Edward Avenue is featured in his *Plan for the National Capital*. The boulevard of trees was removed in 1965 when Dutch elm disease (DED) struck, to be replaced with additional lanes of traffic, as the avenue became the main traffic artery leading to a new interprovincial bridge.[17] The tree-cutting coincided with a devastating urban renewal project that destroyed the fabric of the neighbourhood, and the avenue has attained iconic status in the memory of Lowertown residents as a symbol of all that they lost.[18] (See Figure 6.6.)

The loss of tree cover on this one avenue skews the results for the entire neighbourhood. If we take this avenue out of the analysis, the tree cover in this working class neighbourhood was only 22 per cent in 1946, declined to 9 per cent in 1956, and then hovered in the low teens until it reached 18 per cent in 2005. Analysis of a second study area in Lowertown showed a similar pattern: 16 per cent cover in 1946; 6 per cent in 1954; 11 per cent in 1976; 8 per cent in 1983, and 15 per cent in 2005. This is the same pattern noted in other neighbourhoods in the inner city. The adjacent neighbourhood of New Edinburgh dropped from 20 per cent in 1928 to 19 per cent in 1956. New Edinburgh, however, was not impacted by urban renewal. (They successfully resisted plans to run the interprovincial artery adjacent to their neighbourhood.) As New Edinburgh gentrified, the canopy cover recovered to 23 per cent in 1966, and 26 per cent in 2005. In a third inner-city neighbourhood, Golden Triangle, the canopy cover dropped from 27 per cent in 1950 to 20 per cent in 1966 and 18 per cent in 1990 and

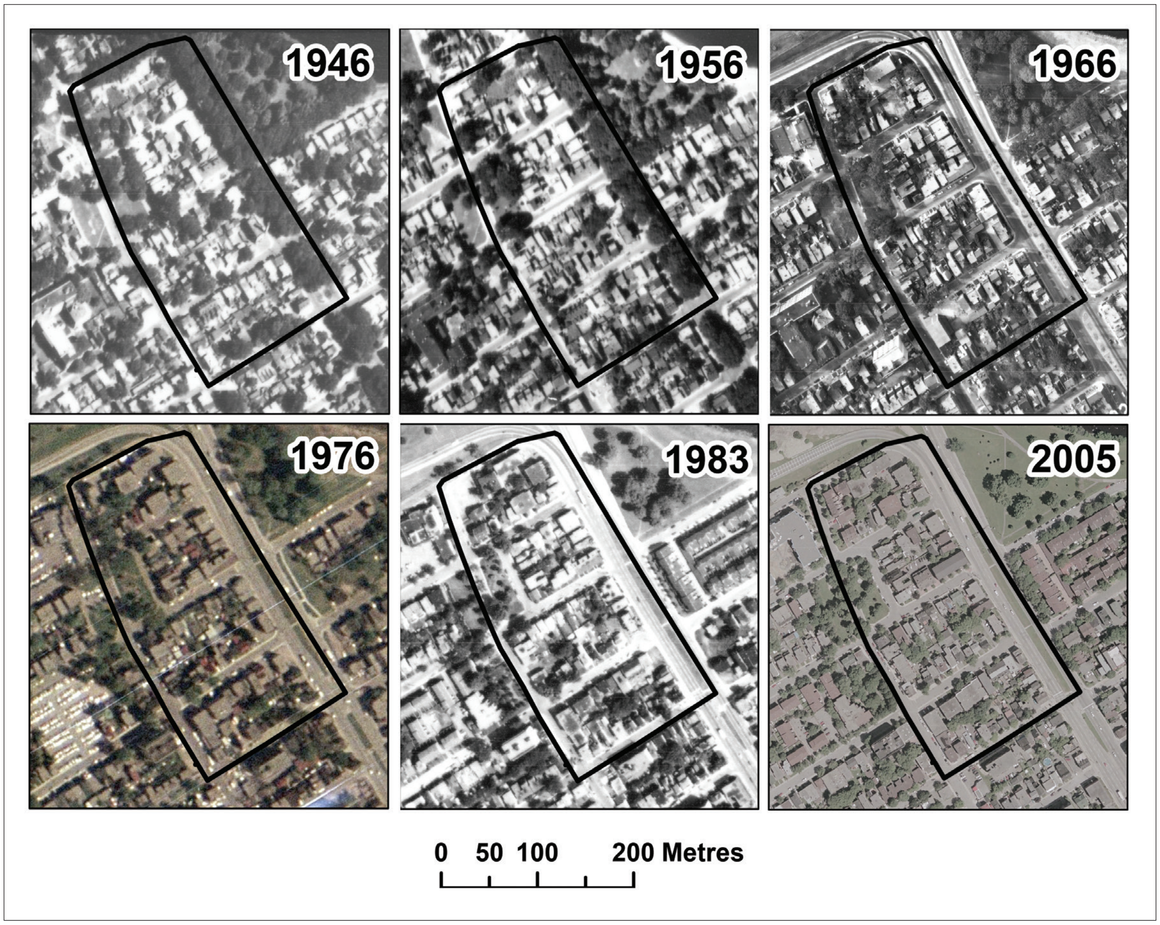

Fig. 6.4. Lowertown. Close analysis of canopy cover in this inner-city neighbourhood demonstrates that the urban forest is an inequitably distributed environmental benefit. Not only is canopy cover currently lower than that of wealthy neighbourhoods, like Alta Vista (see Fig. 6.7), but the densest cover in Lowertown was for many years along one federal boulevard, King Edward Avenue, on the right. In 1946, overall canopy cover was 32 per cent, but if King Edward Avenue is removed from the analysis, the cover on the adjacent residential streets was only 22 per cent. In the 1960s, the trees on this avenue were removed because of Dutch elm disease, and the avenue is now a six-lane interprovincial highway. For street-level photographs of King Edward Avenue, and a sense of neighbourhood anger at the loss of this boulevard, see the King Edward Task Force website, available at http://www.kingedwardavenue.com. (Aerial photographs courtesy of the National Air Photo Library [Series A10371,2; 1946] and City of Ottawa [2005].)

Fig. 6.5. Changes in canopy cover for Lowertown from 1946 to 1950.

has recently risen to 22 per cent in 2005. In all three neighbourhoods, we observe dramatic declines in the middle of the twentieth century and a varying degree of recovery subsequently. These figures, combined with street-level photographs, support the conclusion drawn from textual evidence that the canopy cover was relatively dense in the 1920s and thin in the 1960s.

We might attribute the decline to the management policies of the City of Ottawa. American elm was a favourite tree in Ottawa, as in most cities in eastern North America, and was so thickly planted that it became a problem in the 1920s. Municipal records show that the City engaged in a radical program of tree-trimming and removal to control fast growing "nuisance" trees in the 1930s and 1940s: over 4,000

Fig. 6.6. King Edward Avenue, ca. 1960. Lowertown was subjected to a massive urban renewal project in the 1960s. Photographs justified renewal by documenting poverty in the neighbourhood; they reveal the presence of mature trees planted by an earlier generation. (291–293 King Edward Avenue, ca. 1960. City of Ottawa Archives/2009.0413.1/CA15960.)

trees were removed between 1921 and 1945.[19] Dutch elm disease brought an unexpected denouement. The disease hit Ottawa in the 1950s, after moving from the United States through Toronto and Montreal, and its impact was only felt in the 1960s and 1970s as the elm trees disappeared from the streetscape. But municipal foresters were cognizant of the impact in other cities and reviewed their street tree policy in 1956. They increased tree planting dramatically, planting a total of 2,600 street trees in 1961 (a significant number in a city with a total of 55,000 shade trees, especially compared to 24 trees planted in 1944) and called for street tree planting and improved management and conservation of existing trees in a 1962 report.[20] Municipal authorities noted the dearth of trees in inner-city neighbourhoods and blamed the residents "in the central wards where too many people are inclined to believe that shade trees are part of the past, or that they are the sole responsibility of the Department."[21]

ALTA VISTA, 1946–2005

Analysis of the Alta Vista suburb, in Fig. 6.7, shows the impact of suburban development on forest cover.[22] Alta Vista was an upper-middle-class suburb, developed in the 1950s to the southeast of Ottawa. We initially selected two areas for mapping: 1) an agricultural area, which had only hedgerows and a few individual trees prior to development; and 2) a forested area. Mapping both areas together, we found that canopy cover nearly halved in ten years of construction, dropping from 57 per cent to 29 per cent between 1946 and 1956. It recovered slowly to 34 per cent over the next thirty years and then twenty years later to 48 per cent. (The numbers are high throughout because the mapping area includes a woodlot that was held in reserve for future highway development.) The lesson here is that canopy cover recovers after suburban development but does so very slowly.

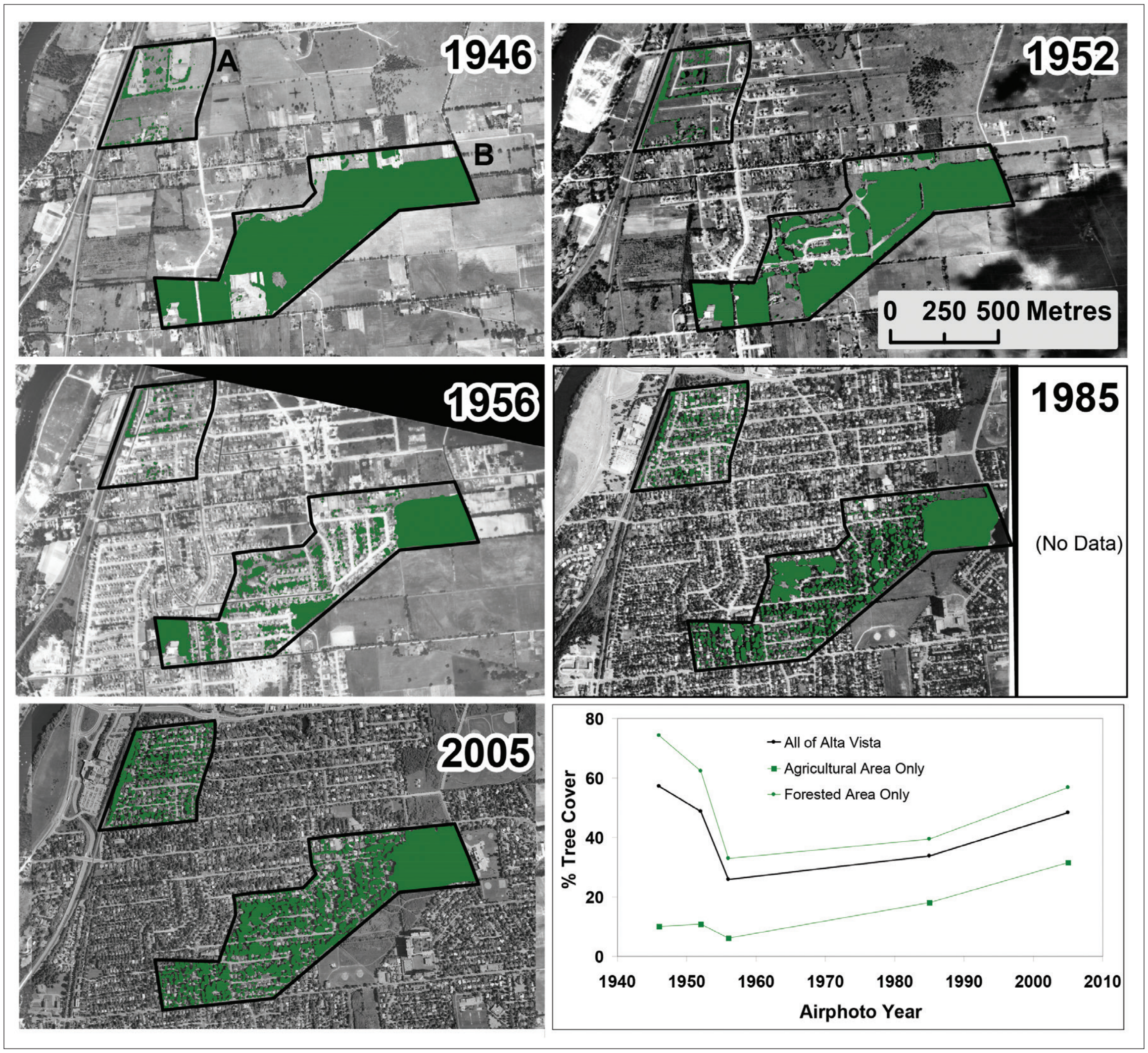

Fig. 6.7. Alta Vista. This prosperous postwar suburb is known for its large lots and mature trees. Two areas were mapped in order to compare the impact of suburban development on open fields and on a dense woodlot. The canopy cover in Area A (see 1946 photo), which began as an agricultural area, was only 10 per cent before construction in 1946. It dropped further to 6 per cent in 1956 with the construction of roads and houses. By 2005, canopy cover had rebounded to 31 per cent. The canopy cover in Area B (see 1946 photo), the original woodlot, was 96 per cent in 1946. It dropped precipitously with construction to 18 per cent in 1956. By 2005, this area had returned to half of its original canopy cover, at 46 per cent. This new forest, however, includes a large proportion of ash trees, now threatened with emerald ash borer. For a complete series of canopy cover mappings of Alta Vista, see http://www.carleton.ca/~jdean/urbanforest.htm. (Aerial photographs courtesy of the National Air Photo Library [Series A 10347, 26; 1946] and City of Ottawa [2005].)

We then analyzed the agricultural area alone (see the region labeled 'A' in 1946 image, Fig. 6.7). Canopy cover here was very low initially, at 10 per cent, and it fell further to 6 per cent before rebounding as new homeowners planted shade trees. It surpassed the original measure in 1985 when it reached 18 per cent and by 2005 had tripled to 32 per cent. It is not perhaps surprising but still useful to know that this kind of low-density suburban development offers a better forest cover than agricultural areas.

Finally, we identified a small densely forested area with 97 per cent canopy cover in 1946 (see the region labeled 'B' in 1946 image, Fig. 6.7). The decline of canopy cover in this area with suburbanization was dramatic, dropping to 18 per cent in 1956, and the recovery fifty years later had only reached about half of the original canopy cover at 46 per cent. The lesson here? The canopy cover in even the greenest suburb is a poor replacement for a forest.

The analysis shows that Alta Vista was the beneficiary of renewed interest in trees in the 1950s and 1960s. Lots in suburban Alta Vista were spacious, especially compared with Lowertown, and thickly planted with large trees. This intent does not show up in the GIS analysis until the trees matured, thirty years after the planting. In Alta Vista, however, the apparent health of the 2005 urban forest is belied by the fact that it is made up of a large number of ash trees. The emerald ash borer (EAB) was first observed in Michigan in 2002 and was confirmed in the Ottawa area in July 2008. This wood-boring beetle has decimated urban forests in southwestern Ontario and parts of the United States and is expected to have a devastating impact in Ottawa. The City of Ottawa has identified Alta Vista as a hot spot for EAB. Ironically, the ash was often selected as a substitute for the America elm; although the ash did not have the elegant vase shape of the American elm, it was a tall tree with dense foliage and offered many of the benefits of elm. Some streets in Alta Vista were planted with 60 per cent ash trees. Tree removals and replacement began in 2011, and a limited program of injections with insecticides began in 2012, but it is expected that the canopy cover in this neighbourhood will be dramatically reduced.

ENVIRONMENTAL JUSTICE

Although natural forces like DED and EAB dramatically impact urban forest canopy cover, social forces are also significant. HGIS allows us to incorporate an environmental justice analysis, using census returns to draw some correlations between canopy cover and the income levels of residents.[23] Our findings are only suggestive as the census areas are not entirely congruent with our mapping areas, but they do consistently suggest that canopy cover follows wealth. Lowertown was a heavily (72 per cent) francophone neighbourhood in 1941, with only 18 per cent of the residents owning their homes, and relatively low median male income of $1,692, 83 per cent of the city average. By 1961 the median male income was $3,219, a relative decline to 69 per cent of the city average. In Alta Vista, by comparison, the median male income was $5,678 in 1961.[24] Although we have not yet correlated income to canopy cover in the remaining urban neighbourhoods, it appears that the recovery of the canopy is related to the gentrification of New Edinburgh and the Golden Triangle. Urban renewal reports of inner-city neighbourhoods provide further statistics: substandard buildings are mapped, and charts tabulate the number of residents and the state of the plumbing. It would be possible to correlate these statistics with canopy cover if two inner-city neighbourhoods were compared. Alta Vista, however, was not subjected to intrusive urban renewal surveys, so we were unable to develop further correlations.

There was, however, a significant lag to the correlation with income: prosperous Alta Vista residents had to wait for their trees to grow in 1961, while Lowertown residents benefited for years from turn-of-the-century tree planting efforts. The evidence for time lag in tree canopy cover is significant and shows the importance of a long-term historical analysis of environmental inequities. An analysis of vegetation cover in Baltimore in 1960 and 2000 led the authors to argue that "the landscapes we see today are therefore legacies of past consumption patterns." They explain: "[Our] findings suggest that herbaceous or grassy areas, typically lawns, are good reflections of contemporary lifestyle characteristics of residents while neighborhoods with heavy tree canopies have largely inherited the preferred landscapes of past residents and communities. Biological growth time scales of trees and woody vegetation means that such vegetation may outlast the original inhabitants who designed, purchased, and planted them."[25]

Close analysis also shows a second pattern. In the residential streets of Lowertown, the recent recovery in canopy cover is more apparent than real. The large street trees that dominated the canopy in the 1940s were not replaced. The new street trees are smaller species, such as Japanese lilac and choke cherry, which will never attain the height and breadth of the large silver maples and other forest trees that lined the streets (and crowded the front yards) in the 1940s. Much of the existing canopy cover is provided by large Manitoba maples that have grown to the rear of the buildings. Manitoba maple or box elder are weed trees that self-seed in neglected yards and along fence lines. These trees are considered a liability. Although their extensive canopy provides ecosystem services, they also create a disproportionate amount of disservices such as limbs liable to crack during windstorms, extensive sucker growth, foundation damage from invasive roots and prolific seed production. GIS analysis of canopy cover alone misses this kind of qualitative change.

LIMITATIONS OF HGIS

If used in isolation, the statistics provided by canopy mapping can be misleading. Mapping, for example, measures only breadth and does not take into account the depth of the canopy. A squat Japanese lilac might be the geospatial equivalent to a tall columnar oak. Mapping does not distinguish between species of trees or calculate the biodiversity of the forest. The predominance of ash in the Alta Vista neighbourhood is not apparent on the canopy maps. Nor does the method distinguish between trees on public and private property; something that is significant in the weighing of social benefits and costs of urban trees. In Lowertown, the numbers do not reveal that massive silver maple street trees, managed by the municipality, were replaced in part by Manitoba maples that self-seeded along fence lines and were a private responsibility.

The full potential of the method emerges when it is combined with other sources. Urban foresters use site observations to support their statistics; historians cannot do this, but because trees live for decades, we can with some caution read backwards from existing trees, and we can refer to street-level photographs and textual sources to augment the statistical measures.[26]

Finally, statistics do not tell stories. The numbers do not provide the interwoven narratives of urban renewal and dispossession in Lowertown, the play of federal politics that lies behind the landscaping of King Edward Avenue, and the aspirations that led middle-class residents to drive to the leafy havens on the outskirts of the city in Alta Vista. Statistics do, however, play an important role in environmental history by documenting the material presence of trees. The maps produced in this geospatial analysis provide compelling visual evidence of the dynamic patterns of canopy growth and decline. Geospatial mapping ensures that the stories we tell about the city consider the agency of the natural world.

NOTES

1 For the shifts in attitude, see Joanna Dean, "'Said Tree is a Veritable Nuisance': Ottawa's Street Trees, 1869–1939," *Urban History Review / Revue d'histoire urbaine* 34, no. 1 (2005): 46–57.

2 For a discussion of methodology, see J. T. Walton, D. J. Nowak, and E. J. Greenfield, "Assessing Urban Forest Canopy Cover," *Arboriculture and Urban Forestry* 34, no. 6 (2008): 334–40. For an early historical application of this methodology, see D. J. Nowak, "Historical Vegetation Change in Oakland and its Implications for Urban Forest Management," *Journal of Arboriculture* 19 (1993): 313–19. For politically engaged analysis of historical urban forest mapping, see Nick Heynen's work, especially "The Scalar Production of Injustice within the Urban Forest," *Antipode: A Journal of Radical Geography* 35, no. 5 (2003): 980–98; and "Green Urban Political Ecologies: Toward a Better Understanding of Inner City Environmental Change," *Environment and Planning A* 38, no. 3 (2006): 499–516. For a well designed historical analysis of canopy cover in Twin Cities, Minneapolis, see Adam Berland, "Long-term Urbanization Effects on Tree Canopy Cover along an Urban-Rural Gradient," *Urban Ecosystems* 15, no. 1 (2012). For Canada, see Hiên Pham's analysis of canopy cover in Montreal, T-T-H. Pham, P. Apparicio, A-M. Séguin, M. Gagnon, "Mapping the Greenscape and Environmental Equity in Montreal: An Application of Remote Sensing and GIS," in by S. Caquard, L. Vaughan, and W. Cartwright, eds., *Springer Lecture Notes in Geoinformation and Cartography – Mapping Environmental Issues in the City*. Arts and Cartography Cross Perspectives (2011): 30–48.

3 Nik Heynen, "Scalar Production of Injustice" and "Green Urban Political Ecologies."

4 See, for example, the contents of the journals *Urban Forestry and Urban Greening*, *Arboriculture and Urban Greening*, *Landscape and Urban Planning*, and *Urban Ecology*.

5 Sudipto Roy, Jason Byrne, and Catherine Pickering, "A Systematic Quantitative Review of Urban Tree Benefits, Costs and Assessment Methods across Cities in Different Climatic Zones," *Urban Forestry and Urban Greening* 11, no. 4 (2012): 351–63.

6 Escobedo et al. define 'urban forest' as: "the sum of all urban trees, shrubs, lawns, and pervious soils located in highly altered and extremely complex ecosystems where humans are the main drivers of their types, amounts, and distribution." F. J. Escobedo, T. Kroeger, and J. E. Wagner, "Urban Forests and Pollution Mitigation: Analyzing Ecosystem Services and Disservices," *Environmental Pollution* 159 (2011): 2078–87.

7 See C. C. St. Clair, M. Tremblay, F. Gainer, M. Clark, M. Murray, and A. Cembrowski, "Urban Biodiversity: Why It Matters and How to Protect It," discussion paper provided for the City of Edmonton (May, 2010) available at http://www.edmonton.ca/city_government/documents/Discussion_Paper_8_Biodiversity.pdf). D. J. Nowak, D. E. Crane, and J. C. Stevens, "Air Pollution Removal by Urban Trees and Shrubs in the United States," *Urban Forestry and Urban Greening* 4 (2006): 115–23. For a review of the literature, see Roy et al., "Systematic Quantitative Review."

8 For health benefits, see J. Maas, R. A. Verheij, S. de Vries, P. Spreeuwenberg, F. G. Schellevis, and P. P. Groenewegen, "Morbidity Is Related to a Green Living Environment," *Journal of Epidemiology and Community Health* 63, no. 12 (2009): 967–73. The research on hospital recovery is the oft-cited S. Ulrich, "View through a Window May Influence Recovery from Surgery," *Science* 224 (1984): 420–21. For a skeptical review of the claims for the health benefits of greenspace, see A.C.K. Lee and R. Maheswaran, "The Health Benefits of Urban Green Spaces: A Review of the Evidence," *Journal of Public Health* 33, no. 2 (2011): 212–22.

9 For disservices, see Francisco Escobedo and Jennifer Seitz, "The Costs of Managing an Urban Forest," University of Florida, IFAS Extension, FOR 217 (2009) available at http://edis.ifas.ufl.edu/pdffiles/FR/FR27900.pdf. For cultural differences in tree appreciation, see E.D.G. Fraser, and W. A. Kenney, "Cultural Background and Landscape History as Factors Affecting Perceptions of the Urban Forest," *Journal of Arboriculture* 26, no. 2 (2000): 106–13, and H. Schroeder, J. Flannigan, and R. Coles, "Residents Attitudes toward Street Trees in the UK and US Communities," *Arboriculture and Urban Forestry* 32 (2006): 236–46.

10 R. F. Young, "Managing Municipal Greenspace for Ecosystem Services," *Urban Forestry and Urban Greening* 9 (2010): 313–21.

11 The survey of the literature on urban trees by Roy et al. ("Systematic Quantitative Review.") found that 91.5% of the papers assessed used quantitative methods.

12 Thi-Thanh-Hiên Pham, Philippe Apparicio, Anne-Marie Séguin, Shawn Landry, and Martin Gagnon, "Spatial Distribution of Vegetation in Montreal: An Uneven Distribution or Environmental Inequity?" *Landscape and Urban Planning* 107, no. 3 (2012): 214–24. Thi-Thanh-Hiên Pham, Philippe Apparicio, Anne-Marie Séguin, Shawn Landry, and Martin Gagnon, "Predictors of the Distribution of Street and Backyard Vegetation in Montreal, Canada," *Urban Forestry & Urban Greening* 12, no. 1 (2012): 18–27.

13 See the description of the trees at "Champlain Oaks" at http://champlainoaks.posterous.com. This tree became the focus of a urban forest history exhibit at the Bytown Museum, from January 2012 to September 2012, "Six Moments in the History of an Urban Forest." Tree dating by Michael Pisaric.

14 H. A. Catton, S. St George, and W. R. Humphrey, "An Evaluation of Bur Oak (Quercus macrocarpa) Decline in the Urban Forest of Winnipeg, Manitoba, Canada," *Arboriculture and Urban Forestry* 33, no. 1 (2007): 22–30.

15 For the delayed impact of drought on Norway maples, see J. D. Apple and P. D. Manion, "Increment Core Analysis of Declining Norway Maples, Acer platanoides," *Urban Ecology* 3–4 (1986): 309–21.

16 See, for example, Dalhousie and Cathcart Streets, 1938, Library and Archives Canada/Department of Public Works, fonds/197-140 CP, 1069-147.

17 For a description of the devastating impact of Dutch elm disease, see Thomas J. Campanella, *Republic of Shade: New England and the American Elm* (New Haven, CT: Yale University Press, 2003).

18 See, for example, D. L. Morny, *Farewell My Bluebell: A Vignette of Lowertown* (Ottawa: 1998), which opens with a description of King Edward Avenue. See the King Edward Task Force website at http://www.kingedwardavenue.com/ for Gréber's and other historic photographs of the iconic avenue.

19 For a full discussion of this campaign, see Dean, "Said Tree is a Veritable Nuisance." For annual numbers, see Julian Smith and Associates, Sandy Hill West Heritage Conservation District Study (Ottawa: September 1993), B10–B12. Joann Latremouille, landscape architect and historian for this report, brought these figures to my attention.

20 J. Alph Dulude, "Shade Trees and Parklands: Planting, Cultivation and Preservation," September 1962, 2, part 3, Specific Surveys and Policies, City of Ottawa Departmental Reports. Submitted to the City of Ottawa Recreation and Parks Committee by the Commissioner of Recreation and Parks, p. 9.

21 Ibid.

22 See Joanna Dean, "Mapping Alta Vista," at http://www.carleton.ca/~jdean/urbanforest.htm.

23 For detailed results, see Joanna Dean, "The Social Production of a Canadian Urban Forest," in Richard Rodger and Genevieve Massard-Guilbaud, eds., *Environmental and Social Justice in the City: Historical Perspectives* (Isle of Harris, UK: White Horse Press, 2011) .

24 Women's incomes correlate less clearly to status or canopy cover because middle class women often did not work outside the home.

25 C. G. Boone, M. L. Cadenasso, J. M. Grove, K. Schwartz, and G. L. Buckley, "Landscape, Vegetation Characteristics and Group Identity in an Urban and Suburban Watershed: Why the 60s Matter," *Urban Ecosystems* 13 (2010): 255; T. R. Tooke, B. Klinkenberg, and N. C. Coops, "A Geographical Approach to Identifying Vegetation-Related Environmental Equity in Canadian Cities," *Environment and Planning B: Planning and Design* 37 (2010): 1040–1056; Lee and Maheswaran, "Health Benefits of Urban Green Spaces"; and N. Heynen, H. A. Perkins, and P. Roy, "The Political Ecology of Uneven Urban Green Space: The Impact of Political Economy on Race and Ethnicity in Producing; Environmental Inequality in Milwaukee," *Urban Affairs Review* 42, no. 1 (2006): 3–25.

26 The method also provides little sense of the large proportion of the tree that exists underground and out of sight. Urban foresters are increasingly aware of the significance of the root system, and the impact of water table changes and soil conditions on tree health. Mapping changes to the built environment, such as changes to the area covered by hard surfaces, might provide some indication.