New Possibilities for Virtual Street Tree Inventories

By Adam Berland and Lara A. Roman

Urban forestry professionals can use online tools to learn a lot about a site before a field visit. For example, Google Street View™ (GSV) provides street-level panoramic photographs that can be used to preview a street tree that is slated for maintenance or removal so that an arborist can anticipate what equipment will be needed in the field. Using street-level imagery, a person may be able to record the tree's street address, identify its species, estimate its size, note overhead wire conflicts, and so on. If this is possible for one tree, could we reliably use online resources like GSV to conduct an inventory of street trees across an entire city?

This idea has already been applied in municipal forestry. In 2016, city arborists in Philadelphia, PA, used street-level imagery from CycloMedia—a company that produces high-resolution streetscape panoramas—to map the locations of over 100,000 street trees, saving the city time and money compared to a field inventory (Maldonado 2016). This virtual inventory was useful for noting standing dead trees, which enabled city arborists to initiate work orders for removals. In this case, the virtual inventory was not used for species identification, and the city is currently carrying out a more traditional field-based inventory to gather more detailed tree data. As other municipalities decide whether a virtual street tree inventory is right for them, more information about data quality is needed to understand which tree variables can be generated reliably using this type of approach. This article provides an overview of research on this topic, with emphasis on the pros and cons of virtual tree surveys, recommendations for implementing a virtual survey, and emerging technological innovations for automating street tree inventories.

Virtual Street Tree Surveys

GSV photographs cover most of the streetscapes in the US, along with many other countries around the world (Google Maps 2019). With the ability to pan and zoom while moving along streets, GSV allows users to focus in on individual street trees, although it is not possible to discern all the details of a tree that a field crew would see.

Two recent studies investigated the level of data quality that could be achieved via GSV virtual surveys in which analysts used visual interpretation to record data about street trees; the virtual survey data were compared to field data for the same locations to assess data quality. Berland and Lange (2017) relied on one analyst with urban forestry experience to inventory street trees in metropolitan Cincinnati, OH, using GSV. In another study in suburban Chicago, IL, sixteen volunteers were recruited to gauge the overall performance of GSV virtual surveys and also to understand how data quality varies according to the expertise of the analyst, from unexperienced novices to urban forestry experts (Berland et al. 2019).

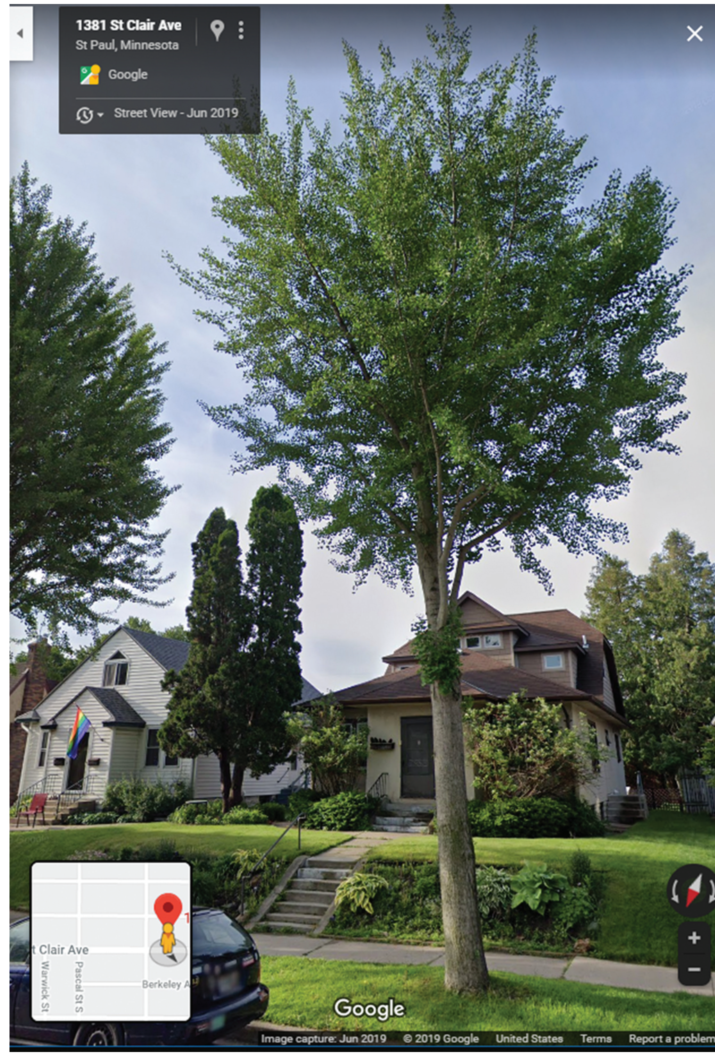
In both studies, the analysts were successful in documenting the locations of street trees, as more than 92% of trees recorded in the field were also captured in virtual inventories. However, analysts underestimated tree diameter at breast height (dbh) about 60% of the time (Berland et al. 2019), although dbh estimation improved markedly after the analyst received midstream performance feedback (Berland and Lange 2017). Genus identification was good for experts (89% accurate) and intermediately skilled analysts (87%), particularly for common trees (Berland et al. 2019). But species identification was considerably less accurate across all expertise groups, ranging from 54% to 73% accuracy for novices and experts, respectively. Berland et al. (2019) asked volunteers to rate their tree identification confidence. Virtual survey analysts were in agreement with field data at the species level for 90% of trees when they were confident in their identifications, but this number dropped to 50% when they were somewhat confident, and down to just 23% when analysts were not confident. This means that self-reported confidence levels can meaningfully reflect species identification accuracy.

On average, the expert virtual survey analysts inventoried trees in less than half the time it took field crews to do the same amount of work: 1.45 minutes per tree for individual experts conducting virtual surveys vs. 3.14 minutes per tree for a two-person field crew (Berland et al. 2019). Time savings were not apparent for analysts with less expertise, seemingly because these analysts needed more time to identify tree species. The analysts were not asked to assess tree condition or record evidence of pests or pathogens because these tasks are difficult to complete without inspecting the tree on site, although GSV can be used to identify easily visible infestations such as the silk nests of pine processionary moths (Rousselet et al. 2013).

Recommendations for Virtual Surveys

Clearly, virtual street tree surveys are no substitute for on-site assessments by certified arborists, for example, to find evidence of pests or structural hazards. Similarly, GSV inventories are not likely to succeed where GSV photographs are sparse, outdated, or have obstructions like vehicles blocking the view of trees. But even where recent GSV photographs are available, a GSV inventory may not meet the needs of a community. Existing studies provide practical, research-based information about the pros and cons of using GSV virtual surveys to generate street tree inventory data. First, GSV inventories can efficiently produce reliable data for basic characteristics like tree locations and mortality status (Leatherbarrow 2019), but data quality suffers for more detailed information like species identification (Berland et al. 2019), particularly for small-statured trees and species that lack obvious distinguishing characteristics when viewed from afar. Consider collecting identification data at the genus level, and if species information is recorded, ask analysts to also rate their confidence in each identification, as confident ratings can typically be trusted while unconfident identifications should be checked in the field (Berland et al. 2019).

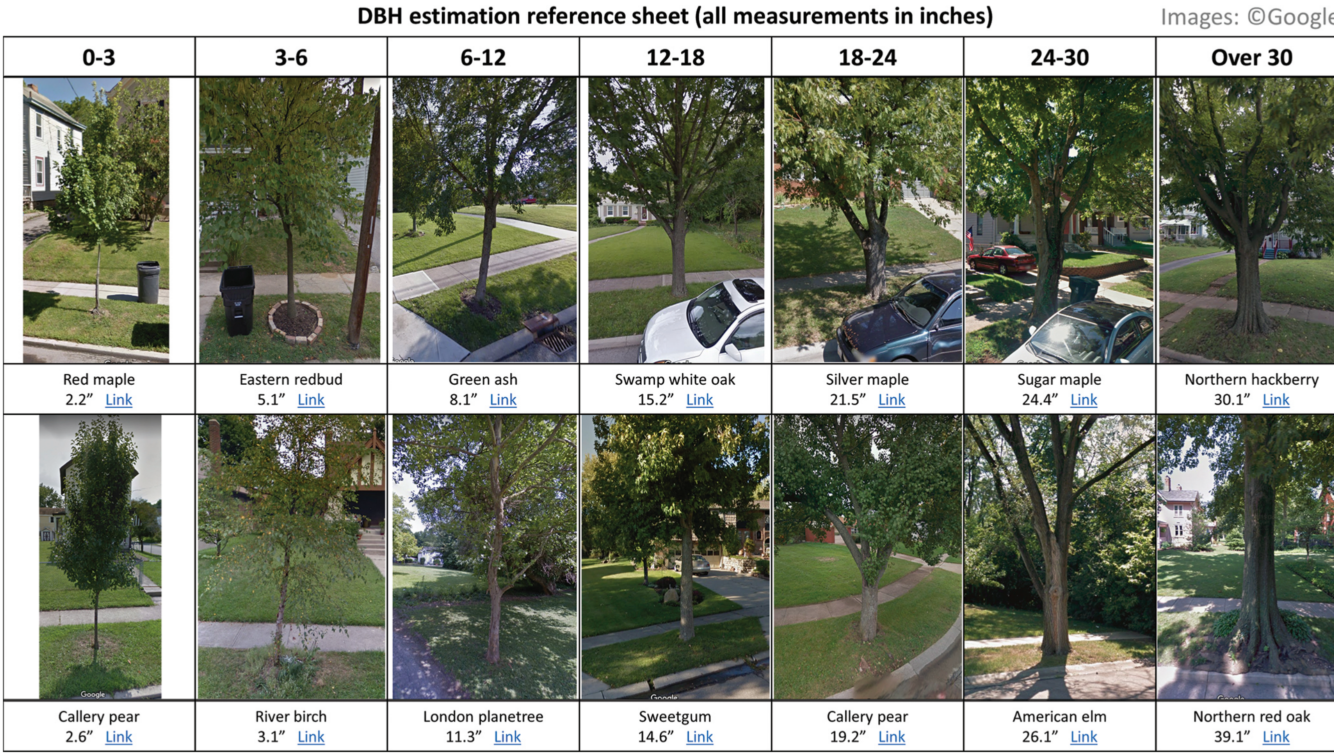
Second, and related to the previous point, even novice analysts can produce reliable data on tree locations, but novices perform more poorly and more slowly when they are asked to record more detailed data (Berland et al. 2019). Communities could explore the use of crowdsourced data to engage the public in the virtual tree mapping process, but we suggest keeping the data collection process limited to very simple observations like tree presence and mortality status. This would give municipal forestry personnel an idea of how many trees they manage and which neighborhoods have more trees than others, but it would not provide information about species diversity or size class distributions. Berland et al. (2019) coordinated data collection with sixteen volunteers completely online using email communication, digital training materials such as YouTube™ videos and PDF documents with links to additional information on the web, and data entry in Google Sheets™. A link to these digital resources is provided at the end of this article. This allowed volunteers to work at their own pace, and the only requirement for participation was a computer with an Internet connection. While virtual surveys may not capitalize on the in-person citizen engagement opportunities



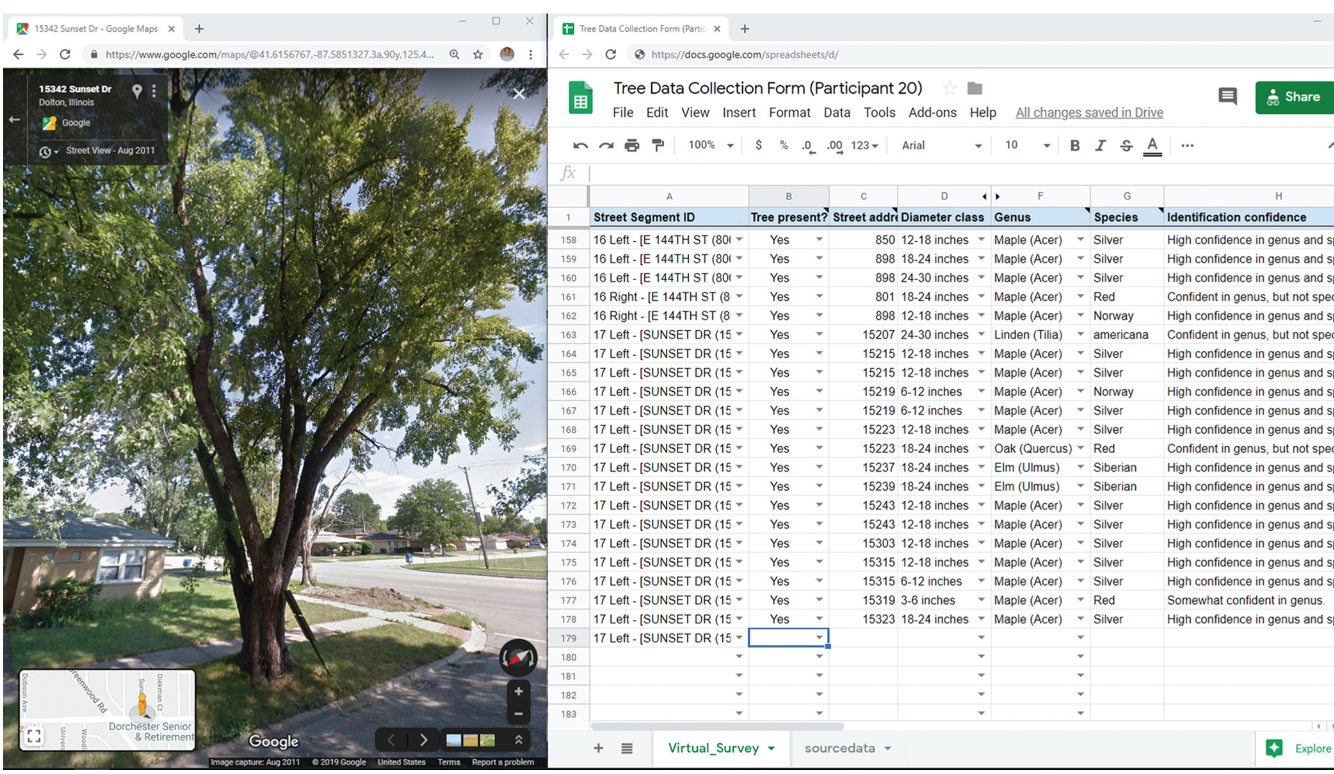
Google Street View™ photographs can be used to complement or replace field work when conducting street tree inventories, but data quality suffers when analysts are asked to record more detailed tree characteristics. Here, we can record the precise location of this ginkgo tree and estimate its size, but we cannot measure the tree precisely or inspect for hazardous defects. Image: © 2019 Google.

presented while walking through the community during a field inventory, virtual surveys may be able to engage volunteers with limited mobility or with interests in technology. Online crowdsourcing has been successful in other research sectors, such as the Zooniverse platform (https://www.zooniverse.org), which has projects ranging from identifying astronomical phenomena to categorizing wildlife to mapping kelp locations.

Third, in light of difficulties reliably identifying tree species and estimating dbh using virtual surveys, we recommend using this approach for a limited set of applications: producing a baseline street tree map in a community lacking field inventory data (Maldonado 2016), updating existing inventories (Berland et al. 2019), or checking for mortality of street trees from a planting program (Leatherbarrow 2019). Based on our experience, an analyst



Virtual street tree surveys can be facilitated using online training materials, including reference materials to aid in dbh estimation (pictured) and species identification; YouTube™ videos to demonstrate workflows; PDF documents to provide data collection instructions; and hyperlinks to data collection forms and additional Internet resources.



Using visual interpretation, an analyst views trees in Google Street View™ (left) and enters tree data in Google Sheets™ (right). The data sheet includes dropdown menus where possible to reduce data entry errors. The data recorded by the analyst is automatically shared with the project coordinator.

could quickly and reliably compare GSV imagery to an earlier field inventory to record where trees were still growing, where trees had been removed, or where new trees had been planted. Given the potential time savings associated with virtual surveys, communities could explore a hybrid approach in which virtual surveys are used to inventory easily identifiable species in clear photos, and the more difficult trees are flagged for field inventory using street addresses or GPS waypoints. Furthermore, a field inventory is still the best option for collecting reliable data on species, dbh, evidence of pests and pathogens, and risk assessment. See Berland et al. (2019) for additional recommendations for implementing virtual surveys.

Automation on the Horizon

While virtual street tree surveys using visual interpretation of photographs can potentially save time and money compared to field inventories, emerging computing techniques are creating new possibilities for street tree data collection. Several recent studies have automated the process of quantifying streetscape vegetation throughout cities. For example, GSV has been used in the northeastern US to calculate tree canopy cover (Seiferling et al. 2017) and a green view index (Li et al. 2015) and to estimate shade provision from trees in Singapore (Richards and Edwards 2017). Tencent Street View imagery was used to quantify streetscape greenery in 245 Chinese cities (Long and Liu 2017). These techniques typically summarize green cover for an entire street-level photo, yet they do not yield information about individual trees.

A recent study by Branson et al. (2018) is particularly intriguing because it does produce an inventory of individual street trees, which is a fundamentally useful resource for street tree management. This approach is rooted in computer vision, a field of computer science that trains computers to extract information from images, emulating the way humans use their eyes to gain information. Here, Branson et al. (2018) used convolutional neural networks to train the computer to "see" trees based on colors, shapes, and textures. Once the computer is trained, it can comb through GSV photographs and plot the locations of thousands of trees within hours compared to weeks or months for humans to complete the same work. In a case study in Pasadena, CA, the computer vision technique successfully mapped about 70% of street trees (Branson et al. 2018), which is substantially lower than work by either field crews or virtual survey analysts. However, the technique was comparable to citizen science volunteers (Roman et al. 2017) in terms of species identification accuracy (over 80% accurate for the 40 most common species in the study area), and the authors note the possibility of adding features such as dbh estimation in the future (Branson et al. 2018). Ongoing advancements in this area could revolutionize the way that cities acquire street tree inventory data.

Conclusions

Field surveys remain the most common approach for collecting street tree inventory data, but publicly available products like GSV offer street-level photographs that have opened the door to new methods. Like field surveys, virtual surveys still require manual data collection by analysts, but they can be completed at any time with nothing more than a computer and an Internet connection, and the data are reliable for basic details like tree locations and mortality status. While arborists will remain vital for conducting tree risk assessments and maintenance activities in the field, the recent development of automated routines for generating street tree inventory data using computer vision points to a more prominent role for advanced technology in the future.

Resources

Digital resources for conducting virtual street tree surveys are available at http://cardinalscholar.bsu.edu/handle/123456789/201769.

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MULTIMEDIA SPOTLIGHT

Texas Urban Forest Strike Team Deploys for Hurricane Harvey, September 2017

An Urban Forest Strike Team is a group of highly-trained specialists. They are certified arborists and foresters who follow the national incident command system and use geospatial mapping to record their on-the-ground findings. They come from local, in-state, and out-of-state jurisdictions to respond both at home and across the country.

Media type: video, 2 mins

Cost: none / free

Where to watch: https://www.youtube.com/watch?v=02g5ufAWi3Q

More info: For more information on Urban Forest Strike Teams, visit: https://www.southernforests.org/urban/ufst

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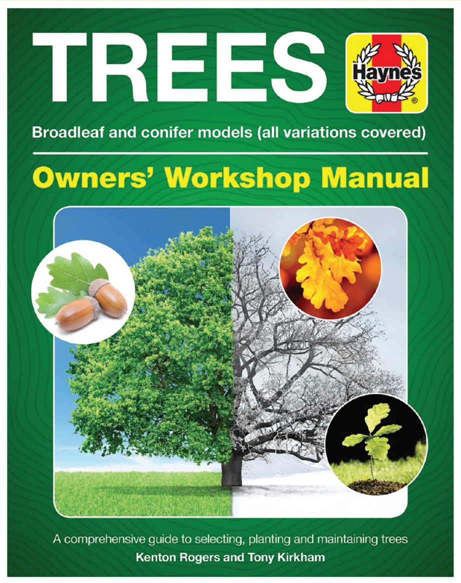
BOOK REVIEW

Rogers, K., and T. Kirkham. 2019. *Trees: Owners' Workshop Manual*. Sparkford, Somerset, UK: Haynes Publishing. ISBN: 978-1-78521-201-7.



Haynes manuals have long been a staple for vehicle owners seeking details about specific models. Taking the concept and applying it to trees is an interesting variation on the theme. The subtitle "A comprehensive guide to selecting, planting, and maintaining trees" is ambitious. The manual has seven chapters, starting with the basics of *What is a Tree?* From there, the sections cover choosing your site and tree, selecting and buying a tree, tree installation, tree pruning, maintaining tree health, and troubleshooting. The appendices provide tree species profiles and useful documents such as site checklists, maintenance schedules, inspection forms, and service records.

The book is clearly aimed at the tree owner. The materials are well written, and the diagrams, sketches, and full colour photographs are all excellent quality and easy to understand. Parts of the book are a series of "how to" instructions, and these are nicely laid out and illustrated in a way that provides good guidance for everyone. Throughout the book there are sidebars containing supplementary snippets of information, and this works well to add content to the overall book.

Inevitably, attempting to provide a comprehensive manual for all circumstances cannot cover every nuance, and some generalisations occur. The section on topping is an example, reiterating the well-worn list of bad things such as increased risk, but failing to note that risk involves having a target of concern. A mention of the Resistograph® in an illustration is used incorrectly (it's a trademark belonging to Rinntech), and there are other places where more nuanced details would have improved the technical content. But overall the homeowner will probably not notice these minor issues.

Some of the specific contact details in the book are very much written for an audience in Great Britain, but the general principles and guidance have global applicability. Haynes Manuals have a long-established reputation as excellent sources of practical information, and this addition follows in that tradition.

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