4-30-2019

Tools For Growth: A Case Study Processing UC Green's Planting Records Using Remote Software Tools

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Leatherbarrow, Ethan Eric, "Tools For Growth: A Case Study Processing UC Green's Planting Records Using Remote Software Tools" (2019). *Miscellaneous Papers*. 17.
https://repository.upenn.edu/miscellaneous_papers/17

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Abstract

Urban tree inventories typically require extensive field work for data collection, but a new software tool has been developed to remotely determine an urban forest's features using publicly available online images. In this study, tree planting records from UC Green were processed for current features and environmental impacts using only remote data collection and data management tools. Trees in the organization's planting record were first located geographically, identified by genus and species, and then algorithmically measured for diameter. After aggregating and verifying fifteen years of bi-annual planting records and processing them with the remote tools, the full record was entered into a live database to facilitate monitoring and maintenance, and then analyzed for its provision of ecosystem services. Out of 1485 street trees confirmed planted by the nonprofit, 1232 were found to be presently living with the most common species being *Syringa reticulata* (Japanese tree lilac), *Acer rubrum* (red maple), and *Gleditsia triacanthos* (Honey locust). Some key impacts of this work were determining the size and scope of the nonprofit's planting accomplishments, as well as estimated ecosystem services, and the facilitation of future monitoring and planting operational performance assessment. The impacts of the UC Green's tree plantings can be increased further as operations are augmented according to the suggested recommendations, which were based on the study's results.

Keywords

Urban Forestry, Tree Inventory, Remote Data Collection, Street-level imagery

Disciplines

Other Forestry and Forest Sciences

TOOLS FOR GROWTH:

A CASE STUDY PROCESSING UC GREEN'S PLANTING RECORDS USING REMOTE SOFTWARE TOOLS

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SUBMITTED APRIL 30TH 2019

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ABSTRACT

Urban tree inventories typically require extensive field work for data collection, but a new software tool has been developed to remotely determine an urban forest's features using publicly available online images. In this study, tree planting records from UC Green were processed for current features and environmental impacts using only remote data collection and data management tools. Trees in the organization's planting record were first located geographically, identified by genus and species, and then algorithmically measured for diameter. After aggregating and verifying fifteen years of bi-annual planting records and processing them with the remote tools, the full record was entered into a live database to facilitate monitoring and maintenance, and then analyzed for its provision of ecosystem services. Out of 1485 street trees confirmed planted by the nonprofit, 1232 were found to be presently living with the most common species being *Syringa reticulata* (Japanese tree lilac), *Acer rubrum* (red maple), and *Gleditsia triacanthos* (Honey locust). Some key impacts of this work were determining the size and scope of the nonprofit's planting accomplishments, as well as estimated ecosystem services, and the facilitation of future monitoring and planting operational performance assessment. The impacts of the UC Green's tree plantings can be increased further as operations are augmented according to the suggested recommendations, which were based on the study's results.

KEYWORDS: Urban Forestry; Tree Inventory; Remote Data Collection; Street-level imagery

DISCLAIMER

This data was collected using a software tool created with support from the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2018-33610-28220 of the Small Business Innovation Research Grants Program. Any opinions, findings, and conclusions, or recommendations expressed in this capstone are those of Ethan Leatherbarrow and do not necessarily reflect the view of the U.S. Department of Agriculture.

INTRODUCTION

Urban tree planting programs contribute to the social fabric of their cities by hosting events, enabling civic engagement, and doing environmental advocacy. However, there are other environmental contributions that can be more difficult to measure than counting the number of volunteers engaged or hours spent educating. In an attempt to simplify the process of measuring those other ecosystem service contributions, they will be broken into three categories of impact: environmental benefits, public health benefits, and economic development. Each of those categories can be broken down further into the numerous effects that each tree contributes. By realizing the breadth of these effects within each category of impact, the value of measuring them becomes apparent.

Some of the most notable environmental benefits that trees provide include the sequestration of atmospheric carbon (Nowak and Crane, 2002), the removal of harmful pollutants from the air (Nowak et al., 2006), oxygen production (Nowak et al., 2007), the mitigation of storm water runoff (Berland et al., 2017), and the moderation of daily temperatures (Nowak, 2002). Additional effects include protecting cities from biodiversity loss by sustaining natural habitats (Alvey, 2006) and supplying the food needs for local insect, animal, and, increasingly, human populations via food forests (Jahnige, 2004).

Trees also directly influence the public health of the societies in which they exist. In neighborhoods with a high percentage of canopy, coverage domestic violence and petty crime rates are reduced (Sullivan and Kuo, 1996; Branas et al., 2018), levels of educational attainment are increased (Sivarajah et al., 2018), and residents express relief from mental health conditions (Beyer et al., 2014). Trees also contribute to a perception of walkable streets (Naderi and Kim, 2006), which directly affects rates of obesity in children and workplace anxiety (Kim et al., 2016). Furthermore, patients who can see leafy biomass from their hospital windows are more likely to heal faster, need less pain medication, and have fewer postsurgical complications (Ulrich, 2002). There has even been a study that discussed reductions in human mortality in relation to urban green spaces (Donovan et al., 2013).

Lastly, there are economic advantages to extensive tree coverage in cities. Buildings with proximate trees show decreases in heating and cooling costs (Ko, 2018) and their estimated property values are increased (Anderson and Cordell, 1985). In tree-lined commercial districts, businesses find an increased willingness to pay for goods, and that customers spend longer periods shopping there (Wolf, 1999). Urban forests also necessitate an expanding job sector for arborists and technicians to care for and maintain them (Bureau of Labor Statistics, 2019). Lastly, the transformation of these resources enables the production of many value-added products ranging from pharmaceutical supplements, to artisanal furniture, to pulp and paper products (Seth, 2003).

Considering all the benefits that exist within each category of ecosystem services, it is clear that urban tree planting programs are capable of making significant contributions to healthy cities, but in order to prove those contributions, each program must first process and analyze their data. Tree inventorying enables programs to measure their historic impacts, demonstrate them credibly, and make estimates about the services they have contributed (Roman et al., 2013). Since most of the environmental benefits that an urban forest contributes are calculated using only three variables, it is essential that any inventory that is taken collects all three of them. Specifically, the essential data is: the geographic location, diameters at breast height, and lastly, genus and species of each tree. When possible, it can be helpful to collect other variables such as site and soil conditions, tree height, crown size, and leaf surface area to gain deeper insights about effects, but this greatly expands the scope and is not objectively necessary.

With the baseline inventory accomplished, other important data management routines can then be undertaken. From the three core variables necessary to a baseline inventory, a planting program is then able to calculate the total contributions within they have made in each category of impact. Program managers can also continue to gain insights about their trees by monitoring their annual growth and mortality rates, as well as other results. By evaluating correlations between changes to planting practices and the survivorship rates of the trees, managers can determine which aspects of their practices could be amended, and which should be retained. The same three core variables that were collected for the baseline inventory should continue to be collected at regular intervals for this purpose. Monitoring the planting record can also advise managers about stewardship and care schedules. Proper maintenance efforts will drastically increase the likelihood of a young tree's survival during its establishment phase (Roman et al., 2015). Clearly, all of these data routines can be extremely beneficial to a planting program.

Acknowledging the benefits of inventorying and monitoring, planting programs will frequently seek out methods that others have used to accomplish the task. The most widely used method for inventorying requires extensive data collection in the field. There are numerous examples of this, at different scales, with ample technological tools, most of which can engage a diverse set of participants, all of whom have varying levels of expertise. Fundamentally, the field data collection method requires people to travel around a city, measure the physical details of trees, and return to a computer to analyze the data. Whether doing an inventory of all trees citywide, in one neighborhood, or monitoring the trees planted through one particular program, field work is the standard means of collecting data. Studies do show that field collection is largely a sound method for accurate data even if citizen scientists are involved (Roman et al., 2017), but depending on the resources available to a program, another method of data collection might be preferable (Nielsen et al., 2014). The programmatic resources required for the field data collection method can be exhaustive, and can represent a significant barrier for small urban forestry programs. This paper presents a case study of managing and monitoring tree planting records for a small urban forestry non-profit in the West Philadelphia neighborhood of Philadelphia, PA who, as a result of the barrier mentioned, never fully completed an inventory using the field data collection method. In order to contextualize the rationale for seeking out and eventually using an alternative method to intensive field inventories, first some background information about the program itself will be provided, and then the process by which the data processing was completed will be detailed.

Background of Study Subject

University City Green (UC Green; www.ucgreen.org) has operated in West Philadelphia for twenty years and in that time this small group has contributed lasting impacts to its community in many forms. Established in 1998 by the University of Pennsylvania's Facilities and Real Estate Services, the organization became an independent 501(c)(3) nonprofit in 2004. Originally, it was intended to serve the area designated as the University City District, but in recent years has included several other neighborhoods within its reach. UC Green's mission states that "through partnerships and education we empower volunteer environmental stewardship in University City and its surrounding communities" via "Cooperative Community Greening." Internally, one or two staff members work alongside a board of directors, but without its network of committed volunteers, none of the organization's programming would be possible.

UC Green operates two main programs, tree plantings and pruning club, and has run other additional programs as well. Primarily, UC Green organizes two street tree plantings a year. As the initial and final point of contact for homeowners, UC Green is the public face of a larger coalition of organizations that facilitates plantings for homeowners who request street trees on their property. The process of homeowners receiving trees is as follows. First, homeowners submit an application to UC Green. Second, the City of Philadelphia's Parks & Recreation Department (the agency that oversees street tree management) issues an individual permit to plant. Then, that permit is passed to the Pennsylvania Horticultural Society (the major urban greening nonprofit in Philadelphia and surrounding counties) so that they can contract an arborist to assess site conditions and suggest a species. Finally, the tree is purchased with Pennsylvania State Department of Conservation & Natural Resources grant funds and delivered to UC Green for volunteers and staff to plant during one of two seasonal planting events. During these planting events volunteers join staff members at a predetermined site, divide into teams, and take the necessary tools and trees out to each site and plant it alongside the homeowner. With only a few operational variations, this street tree planting process has been repeated by UC Green twice each year for two decades.

In addition to plantings, UC Green also hosts a Pruning Club every month during the summer to maintain their young trees. A small group of volunteers will preselect trees that are three to five years old and, with a certified arborist, visit and prune them for advantageous growth. This is not only a chance to ensure healthy growing patterns for the young trees, but also to increase the skillset of the volunteer base. As stated in the mission, UC Green is committed to empowering its community through both education and environmental stewardship in this way.

This commitment to both education and stewardship is also why the organization hosted program called UC Green Corps for many years. By seeking out environmentally minded young people and giving them the skills and equipment necessary to succeed, UC Green was able to employ a cohort of students each summer that would cultivate growth in both themselves, and in their communities. Green Corps members learned land care procedures, leadership skills, and sustained upkeep agreements with neighborhood green spaces. UC Green also hosts a full tool library to enable the pursuit of its mission, even if someone else organizes it. Individuals or organizations who are interested in using their tools are able to borrow them at no cost and receive training should they request it.

Over the years there have been numerous staff and volunteers who have participated in each of these programs, especially the street tree application and planting process. Frequently staff members would delegate administrative responsibilities to volunteers. Unfortunately, this means that multiple styles of record keeping have been used to keep track of the trees planted. There was also recently an internal switch from using paper records to keeping only digital data, which has further delayed the development of any baseline inventory. In the past, all attempts at inventorying UC Green's trees were done in the field by volunteers, staff, or student researchers, but only small portions were ever completed. Obviously, they did not include any new planting data since those attempts either. Impeding the process even more, some of the coalition organizations have also changed their methods for applications, permitting, and purchasing meaning that any tangential documents that might be used to verify or fill gaps in internal records would first require an intensive review. For the reasons mentioned above, neither the initial data management tasks, nor a complete field-based inventory, have been completed entirely. In order to obtain a complete and accurate assessment of UC Green's living tree planting records a combination of both data aggregation and subsequent verification would be required.

Tools for Remote Data Management

Thankfully, as a result of the development of a new remote data collection tool called Treetective, any tree planting program can determine the three core variables necessary to achieve a baseline inventory without ever going into the field. Known in the urban forestry world for their web application Open Tree Map, Azavea built the Treetective tool in order to facilitate doing tree inventories remotely. Under the heading "Beyond Dots on a Map", their website explains how "Azavea creates software and data analytics for the web. We are a mission-driven company, using our nearly twenty years of geospatial expertise to help our clients address complex civic, social, and environmental problems" (2019). In pursuit of their focus on impact, this certified B-Corp recognized the value of enabling tree planting programs to analyze their planting records, as well as the difficulties associated with field data collection, and built the Treetective prototype in response. After initial development, but before public release, UC Green's planting record was processed with the Treetective tool to test the product, because it represented a prime use case scenario for the product itself, and for the variables gleaned.

However, before the use of the new tool was even possible, UC Green's various records had to be aggregated and verified by at least one corroborating document to ensure that the dataset represented the entire planting record as closely as possible. As mentioned, there were internal obstructions to this, and external impediments due to changes in coalition documents, but eventually through the meticulous investigation of both internal paper documents and digital files, a single dataset was aggregated that could be processed using the Treetective tool.

In addition to Treetective, UC Green also used another other software tool to operationalize the planting record and facilitate its future monitoring efforts: The Urban Forest Cloud. Similar to UC Green, the Pennsylvania Horticulture Society (a major urban greening nonprofit in Philadelphia) was concerned about their manual data input and management methods (Roman et al., 2018) and sought out a proprietary software that included monitoring features, but none were available at that time (Boyer et al., 2016). In response, the Urban Forest Cloud web application was developed to feature "a collection of all data gathered for individual trees and projects and enable multiple user groups to update and manage tree information that is stored in a central database and map" (Hanou, 2016). This web-based urban tree management application was developed by Plan-it Geo, an urban forestry software and consulting firm, by adapting their existing product Tree Plotter to include mobile device data collection and other features. The new software tool had two main advantages to paper record keeping: accuracy and efficiency. Even though a manual documentation method is capable of tracking applications, plantings, monitoring, and maintenance, it is much quicker and safer if the human data input element is reduced. This is especially true for the Pennsylvania Horticulture Society in that they are not only tracking one group's plantings, but all of the progress made by planting programs around the city. Since multiple groups were reporting their planting data to them, without the Urban Forest Cloud they were required to manage hundreds of trees planted each season, not to mention any monitoring, maintenance, or removal information. By decentralizing the database, input errors were reduced and efficiency was increased. Essentially, the Urban Forest Cloud system allows the public to submit tree applications via a URL, and planting programs to engage those records at each stage of the tree's life, from planting to removal (or replacement). Realizing the potential of this, UC Green began recording all of its planting data within this system in the fall of 2015. It was for this reason that the planting records had been bisected into both digital and paper records. But, having aggregated the planting data since 2015 with the rest of the historic data using Treetective, it was possible to reinput the complete planting record within the Urban Forest Cloud. At this point UC Green was able to realize the full scope of their planting records, with all the core variables, but were not yet able to calculate any ecosystem services that these trees contributed to the city. To accomplish this, another software tool would be required.

The i-Tree suite of applications was developed for the US Forest Service to enable those who have collected tree inventories to determine what ecosystem services they have contributed (www.itreetools.org/). The i-Tree Eco tool specifically takes the three core variables (at minimum) and estimates ecosystem services by relating them to other credible data sources (Nowak et al. 2008). It also generates various reports that indicate different analytical perspectives about the inventory and its impacts. In the case of UC Green's planting records, these insights would come in multiple forms such as key data highlights for marketing purposes, as evidence of programmatic cost efficiency to secure or retain funding, or even by relating changes in planting practices to fluctuations of impact output for operational performance assessment. Furthermore, having established a baseline of impact output for the planting record, targets and goals could now be set based on historic and projected yearly impacts.

Having determined these insights with the i-Tree Eco tool, consolidated the planting records into the Urban Forest Cloud for ongoing management, and completed the baseline inventory through data aggregation and processing with Treetective, UC Green was able to fully realize the scope of their contributions, as well as the details of their trees in the planting record.

Research Goals

The primary goals of this case study are to provide the data resources necessary for UC Green to define their prior successes in tree plantings, incorporate that information into the current management system, determine the historic impact contributions, and, perhaps most importantly, suggest realistic goals for the program's future based on that data. Secondary goals are to delineate the process by which those data resources were developed, and describe how similar organizations looking to achieve the same ends could replicate it using the same tools. Finally, some tertiary goals include mapping the planting records, selecting some of the most notable data insights for dissemination, and doing a reflective review of this research itself and the process by which it was undertaken and completed.

METHODS

Each stage of data processing was completed using specific methods that were selected for each of the tasks required. In consecutive sequence these processes can be broken down into the following categories: data aggregation, verification, collection, implementation, and analysis. Each of these categories is interdependent in so far as they must be fulfilled in direct succession. Diverging from this order negates the potential for some of these processes to be completed due to lack of data from the others. In order to delineate the process succinctly so that others with the same goals can replicate the sequence, it will be described. The entire process of this case study took roughly four months, with the most time-consuming tasks being data collection, and then verification, aggregation, analysis, and finally, implementation. Researching, writing, and editing of this report was completed in approximately two months.

Data Aggregation

Aggregation began the sequence by sourcing all applicable data from the divergent systems of record keeping and unifying them within one dataset. Comparable to a dragnet, this stage essentially assumed that every variable was valuable and input them all into one dataset. It was important to capture and unify all the available data at this point because later stages require a uniform format for processing. Although aggregating documents implicitly requires merging information that has inconsistent source formatting, priority should be given to those core variables that are needed for later stages of processing. If any of the three core variables are missing from a line item, other information can serve as an adequate placeholder until it is obtained. For example, a tree's geographic position is essential in calculating its ecosystem services during the analysis stage. If records only contain a homeowner's contact information, that variable should be preserved and used to locate the tree during the verification stage. Moreover, no information should ever be discarded. Even if the utility of a variable is not immediately apparent, potential applications may be realized by others later on. Furthermore, metadata about the information's sources should be collected where possible. This metadata can be a source file's name, type (digital or physical) and place, author, and creation date. All of these should be retained in an attempt to expedite the verification process. A simple way to do this is to develop a numeric system for source documents and indicate any that apply to a particular line item within a unique metadata category. At UC Green, many different variables were recorded to fluctuating degrees over the years. Records about recipients, tree procurement, types of tools, volunteer teams, monitoring, and tree care data were all found and aggregated through a meticulous investigation of paper documents and digital files. Anecdotal information was also gathered by collecting oral histories from influential participants (methods ranged from impromptu conversations with members of the volunteer advisory board, to the extensive review a former staff member's administrative notes, to an informal interview with the current executive director). In order to preserve all of this information a list of categories was developed that could contain it all, which is provided in the appendix. After aggregating all the line items, and their interior variables, all the planting record information that was collected was then verified.

Data Verification

The next stage of the data processing sequence essentially examined the credibility of the data aggregated and validated it with a corroborating source. The underlying reason for this was not an assumption that the data was in any way false, but instead was an attempt to protect the integrity of the research and the dataset overall. Early in this stage a determination should be made as to what level of corroboration is required to verify each line item, in this particular case, one document was determined to be all that was necessary. Due to the high volume of data, and the variability of sources for corroboration, requiring more than one source was not a realistic protocol. The verification stage was not intended to authenticate aspects of variables specifically, instead, it was meant to seek out aspects of the dataset itself that were flawed. If an event was listed in the UC Green records as having planted a certain number of trees, other documents had to be found to corroborate that number. Duplicate entries, aberrant data, transcription errors, and missing information were the most frequent issue areas for UC Green's dataset. During this stage the most essential process is to establish the first of the three core variables: geographic location. Determining location is necessary to enable the forthcoming data collection stage. This is the only point of information absolutely necessary for a line item at this point, although as mentioned, every variable is valuable and should be retained when possible. The last process of the verification stage populated gaps in line items with variables taken from corroborating documents. By either filling gaps with information from the corroborating document directly, or by searching out sources from the metadata notes of other complete line items, all possible information for each line item was aggregated and verified.

Data Collection

The collection stage of the data processing sequence essentially completed the inventory and prepared the dataset for operationalization and analysis. It should be noted here that the tool used for UC Green's inventory is not publicly available at this point in time. Even though Treetective's initial development phase has ended, Azavea is in the midst of seeking grant funding to continue building it in a second phase. Presuming their receipt of that, Treetective will be developed further for marketability and increased efficacy. In an attempt to both acknowledge the intellectual property rights of Azavea, as well as delineate the methods that were used to complete the UC Green inventory, a measured explanation of Treetective will be provided.

The Treetective system relies heavily on two external resources: the Google Street View image database for diameter measurement, and the user, to make tree species and genus identifications. The core function of Treetective is to algorithmically measure the distance between two points on an image and record it for export. When aligned with the two sides of a tree, the tool can calculate its diameter. Location is noted implicitly from the Google image. Also, users can record other variables like injury, damage, infestation, and mortality status.

In the processing of UC Green's inventory, each tree's geographic location was first input into a search field to pull up the street view image of it. At that point the user indicated where the tree was in that first image. The tool then automatically opened another view pane showing the adjacent image to the previous one and prompted the user to select the tree again from that second viewpoint. The position of each tree is marked on two adjacent images in order to triangulate its position and determine the exact GPS coordinates. With the location marked, the user was then prompted to use a sliding measurement tool to indicate either edge of the trunk. The user approximated the slide rule's vertical position at standard breast height (1.37 m), and in cases where the tree was too short, diameter was measured below the lowest branch. With the position and diameter recorded, it was then up to the user to make a genus and species identification and input those variables into the appropriate fields. The tree could not be fully logged until all three of the core variables had been input. With those steps accomplished, the next tree in the planting record could be searched for and the process repeated. The inventory was based on the images that were closest to the date November 18th, 2018 for two reasons: this was the date of UC Green's most recent planting, and Google Street View had taken images for the majority of the streets with trees on them later that month (Google, 2019).

Once all of the trees in the planting record had been measured, and their details collected, the data was exported for further processing. Having collected the second and third core variables with the Treetective tool, the planting records were able to be input into the Urban Forest Cloud management system as a baseline and point of reference for future data processing.

Data Implementation

The implementation of the planting records was largely comprised of reformatting the dataset into a document that could be uploaded into the Urban Forest Cloud. Since this is a live database, that has public input protocols, it was important to first ensure that no information (like applications submitted during the other stages of processing) was lost during data transcription. This was done quickly by comparing the total number of records initially aggregated and those present at the time of upload. Before uploading the dataset, the categories of variables that were established during the aggregation stage were directly correlated to the native fields within the tool itself. Some of the terms used were not immediately understandable, and slight distinctions between seemingly similar information might confuse a person. By carefully selecting which input field corresponded to which variable category from the aggregation stage, the dataset was merged into the upload document without too much data loss. For example, the difference between caretaker and homeowner was important to distinguish. If only one set of contact information was retained, it was assumed to be that they are the homeowner, because caretakers do not have approval authority. Some fields, particularly those that deal with maintenance and monitoring, have associated fields for metadata about the variable itself. When a tree was pruned will determine when it should be pruned next, and unless the date of its former maintenance was retained, programmatic resources could be wasted when attempting to determine lost information. In order to preserve as much data as possible, it is important not to rely on the Urban Forest Cloud or any data management software as the central repository for the dataset. There are simply not enough fields within any tool to encompass all of the possible historically collected variables for each tree. Two independent locations should be established for the entirety of the dataset in multiple forms so that all of the previous processing work is not lost as a result of institutional memory deterioration, management system failure, or data loss.

Data Analysis

The final stage in the sequence of data processing was data analysis. Two functions of analysis were completed, the first used a software tool, and the second developed more insights using other methods. The i-Tree suite is quite simple to use, as long as each of the earlier stages of data processing were completed. The three core variables were formatted into the upload document and processed through the system by following the ample instructions provided within the tool's database. It was not necessary, but during UC Green's data analysis one of the three core variable's formats was changed. Species codes were used instead of other common nomenclature forms; these codes are listed in the appendix alongside their Latin and common names, and planting frequency. Translations were done by batch lookup and replacement in Excel. The decision to use codes was an attempt to further unify the format of the planting records overall and to ensure the software itself would recognize each variable.

Based on what information the planting program is interested in obtaining, different analytical reports can be generated. Apart from the core variables, if there is data that correlates to available fields in the upload template, they can be also be included to enable the full breadth of i-Tree's functionality. In UC Green's case, the priority was the recording of the three core variables to facilitate an ecosystem services report only, so no others were input. Apart from the ecosystem services report, only a report about metadata was generated for the UC Green inventory. Beyond the i-Tree generated reports, a few other calculations were also made about the planting records.

Knowing the number of trees planted historically, and the total currently living, a percentage was determined for the planting record's annual survival and overall survivorship rate. Although there are countless reasons why a tree might have died, been removed, or not even processed, it is still helpful to know the overall rate of success. Mortality or removal status were determined based on visual evidence found in Treetective (Roman et al., 2014).

At this point the criteria for data inclusion should be noted. The results only include the trees that UC Green planted through the street tree coalition's supply chain. What is not included are trees that were not sourced with the support of the Parks and Recreation Department and the Pennsylvania Horticulture Society. Some of the larger and more notable planting events such as those at Kingsessing Recreation Center (Roman et al., 2015) and Clark Park (Siano, 2017) are therefore not included. Furthermore, this inventory does not include any trees that were planted in yards, or anything outside the bounds of what is considered a street tree by Philadelphia municipal code. These are not included for two reasons: first, UC Green has not committed to their care and monitoring, and so, they cannot solely claim responsibility for the impacts of those trees over time. Therefore, only trees that were permitted by the city, procured by PHS, and planted during a UC Green event are included. Within these criteria, 1485 street trees were planted by UC Green between the years of 2003 and 2018.

RESULTS

Table 1. Key results summary

Street trees planted	1485
Street trees currently alive	1232 (77%)
Total number species present	72
Most common species	*Syringa reticulata* (Japanese tree lilac)
Average diameter	13.69 cm
Survivorship rate	82.96%
Mortality rate	17.04%
Replacement rate	21.73%
Average volunteers per year	54.19 (Spring 47.73; Fall 60.66)
Pollution removed	100.7 kilograms per year ($2.31k per year)
Carbon storage	107.7 metric tons per year ($20.2k)
Carbon sequestration	5.102 metric tons ($959 per year)
Oxygen produced	13.61 metric tons per year
Rainwater runoff avoided	150.1 cubic meters per year ($354)
Structural Value	$695,000

Total trees planted and currently alive

Of the 1,485 trees that UC Green planted between 2003 and 2018, it was found that 253 of them had died or been removed since planting. It is not the focus of this research to ascertain the reasons for their deaths or removals, and the data collected would not facilitate that, but a mortality status was required for each tree during the inventorying process. This variable was noted in the record by indicating that the tree was either alive (alive), visibly dead upon inspection (standing dead), had been removed entirely (removed), or was replaced (replaced). It should be noted that there was an implicit limitation in capacity to confirm death remotely, so only trees that had very clearly died were marked as standing dead. Any tree that had any leaves with color was presumed to be living. Potentially, trees that appeared to be dead may have prematurely dropped their leaves and seemed deceased when in fact they were alive but, like other variables, a subjective judgement was required and the record reflects those determinations.

Of the 253 that died, 55 were replaced in later years. Although the replacement rate in Table 1 assumes that UC Green was the organization to facilitate these replacements, they are not included in the living tree total because there is no way to confirm that they were not planted by another member of the coalition or by the homeowner. Without the replacements, the total number of trees that were alive as of the November 18th, 2018 inventory date was 1232.

Understanding these figures, UC Green has an 82.96% raw survival rate of their planting record (across all planting years), with a corresponding 17.04% raw mortality rate, and a 21.73% assumed replacement rate. Survivorship rates and annual survival can be seen in Table 2.

Within the course of operations there were some trees that had records, but were never planted. Reasons for this could vary from applications being denied due to poor site conditions, applications being cancelled by the recipient, or trees lost due to logistical errors. The number of trees that have records, but are listed as not planted, is 250. This brings the total number of trees with some type of record to 1735 whether they were planted or not, living or not, or ‘other’.

Table 2. Yearly plantings, survivorship rates, and annual survival

Planting Year	Number of Trees Planted	Number of Trees Survived	Survivorship rate	Annual Survival	Time Interval (Years)
2003	2	2	100%	100%	15
2004	31	10	32.25%	92.23%	14
2005	30	20	66.66%	96.92%	13
2006	8	1	12.50%	84.08%	12
2007	63	38	60.31%	95.50%	11
2008	263	238	90.49%	99.00%	10
2009	494	394	79.75%	97.51%	9
2010	81	77	95.06%	99.36%	8
2011	82	79	96.34%	99.46%	7
2012	69	46	66.66%	93.46%	6
2013	47	43	91.48%	98.23%	5
2014	65	56	86.15%	96.34%	4
2015	38	31	81.57%	93.43%	3
2016	75	73	97.33%	98.65%	2
2017	74	64	86.48%	86.48%	1
2018	63	60	95.23%	95.23%	0
Totals:	1485	1232	77.39%	n/a	

Species and size classes of surviving trees

The oldest trees in the planting records are all fifteen years old, but the largest groupings by age are the 494 trees planted in 2009 and 263 in 2008. As shown in Table 2, these two plantings far exceed any others and could be attributed to the simple fact that the organization employed the highest number of staff members during this period (2). The average number of trees planted per year is 92, with a standard deviation of 117.86.

Among UC Green's living trees, there are 72 different species. The three most frequent are *Syringa reticulata* (Japanese tree lilac) at 10.1%, *Acer rubrum* (red maple) at 7.4%, and *Gleditsia triacanthos* (Honey locust) at 6.4%. Of the 56% that are non-native species, 29% come from Asia. The other 44% of the population are native to North America, and of those, 40% are native to Pennsylvania. The two invasive species, *Acer platanoides* (Norway maple), and *Pyrus calleryana* (Callery pear), represent 2.1% of the total tree population. Staying within the Parks &

Recreation Department's approved planting list, species selection is left up to the preference of the tree recipient, or in lieu of a request, selection is based on the suggestion of the arborist who inspects the planting site. Although all of the trees in the planting records were identified to the species level, 51% of the total can be grouped together because they do not represent enough of the total to be statistically significant. A full list of species frequency is provided in the appendix.

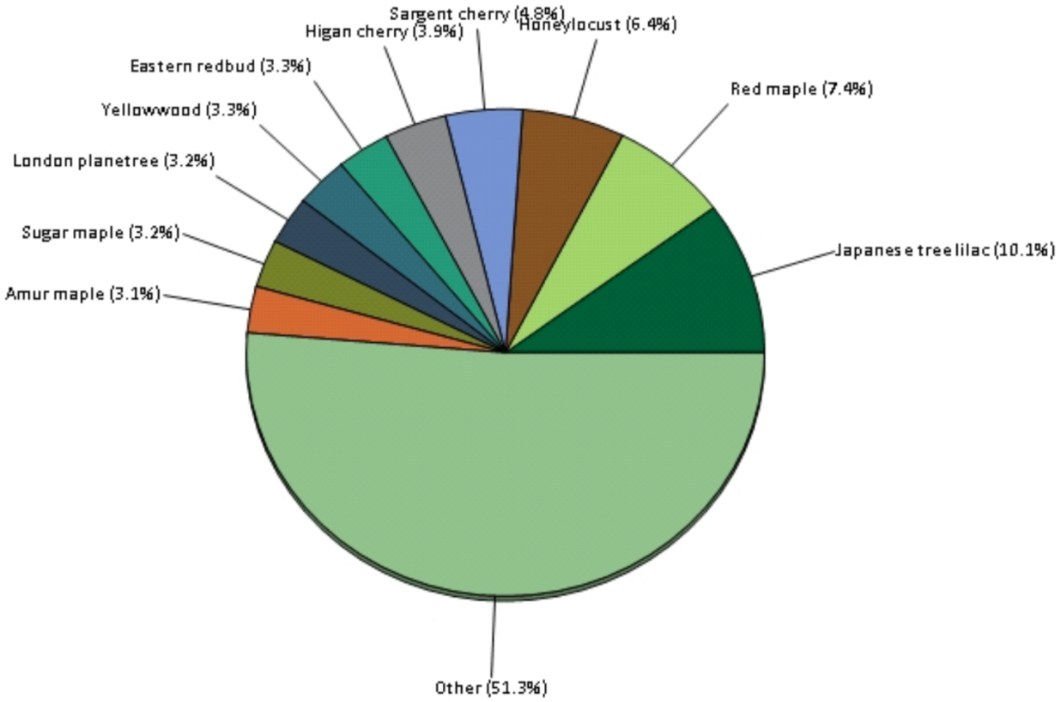

Figure 1. Tree species composition in UC Green inventory

If side by side, the full planting record's size would cover nearly two hectares (1.984), while its leaf area would provide 7.932 hectares of coverage. The most important species by size (calculated as the sum of percent of population and percent of leaf area) are *Acer rubrum* (red maple), *Platanus acerifolia* (London plane tree), and *Syringa reticulata* (Japanese tree lilac).

As can be seen in Figure 2, most of the trees in the planting records (78%) are less than 15.2 cm in diameter and within that, the largest portion is between 7.6 and 15.2 cm (62.41%).

The largest trees in the population are a few *Platanus acerifolia* (London plane tree), with the largest being 93.98 cm, followed by a 78.74 cm *Ginkgo biloba* (Ginkgo).

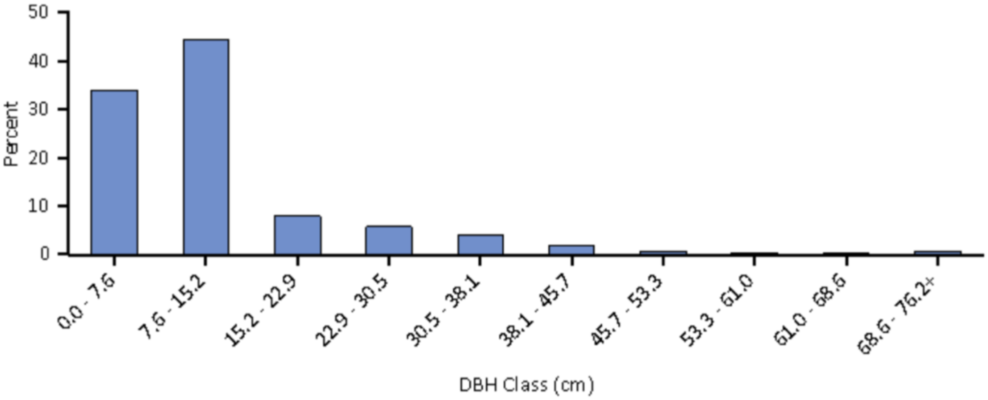

Figure 2. Percent of tree population by diameter class

Data was also collected from planting records detailing the number of volunteers engaged during each tree planting event. Even though an average number of volunteers was calculated for each year, a total number of individual volunteers was not found due to recurring volunteership. Fall events were more popular with an average of 61 volunteers, with Spring events averaging 48 volunteers. Seasonal totals of volunteers engaged can be seen in Figure 3.

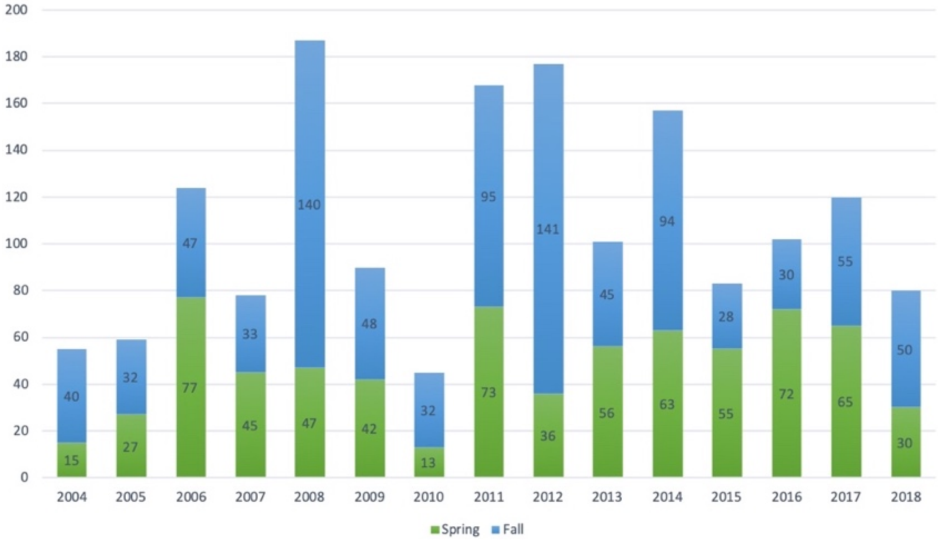

Figure 3. Volunteers engaged each season by year

Geographic distribution

From the spatial density analysis shown in Figure 4, it was determined that the majority of the trees fall in between Woodland Ave and Market St, from 30th to 52nd, and that the rest have a relativity disparate spread. Just 665 of the 1232 (53.89%) living trees grow within the geographic zone that shares a name with the organization, University City, so if one attempts to note the true geographic range of the planting record, a more apt zonal demarcation might be Philadelphia's 3rd City Council district as is indicated by the red area seen in Figure 5.

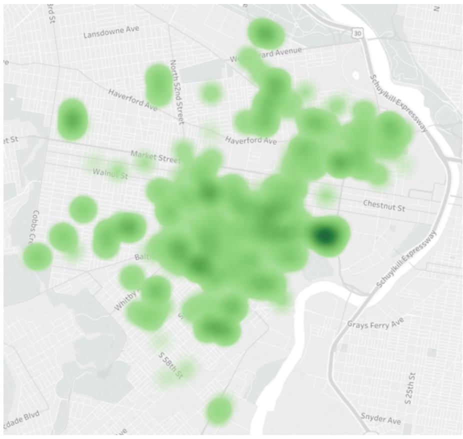

Figure 4. Spatial density in planting record

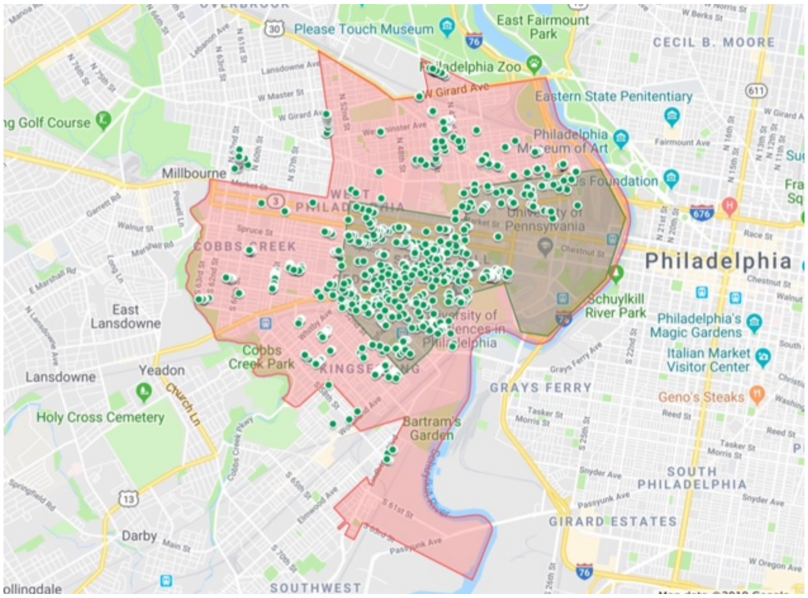

Figure 5. Planting record overlaid on University City & Philadelphia's 3rd city council districts

Estimated ecosystem services

In addition to the physical characteristics, results about the different contributive effects and ecosystem services of UC Green's surviving trees were also gathered.

Globally, the most important effect is likely the planting record's capacity to sequester and store atmospheric carbon that would otherwise contribute to the effects of anthropogenic climate change. That being said, the carbon cost of planting those trees was not calculated and therefore only the net total of carbon either sequestered or stored could be estimated. In total, UC Green's tree surviving trees were estimated to have stored approximately 107.7 metric tons of carbon over the course of its planting history. As of the inventory date in 2018, these trees can sequester 5.102 metric tons per year. The most impactful species by far has been *Platanus acerifolia* (London plane tree) having stored 19.8% of the gross total, and sequestering 9.18% of the yearly total. Other species such as *Acer rubrum* (red maple), *Gleditsia triacanthos* (Honey locust), and *Ginkgo biloba* (maidenhair tree) are also significant contributors as a result of both their rates of sequestration and the gross amount of carbon they have historically stored.

Although trees are frequently cited for their ability to produce oxygen, in fact their contributions are relatively insignificant when compared to the vast amount that is omnipresent within the atmosphere or what is produced by global aquatic systems. Nonetheless, UC Green's planting record has contributed 13.61 metric tons of oxygen annually with, yet again, the *Platanus acerifolia* (London plane tree) being the largest contributing species. Having produced 1244.41 kg of oxygen, the 39 trees of this species clearly dwarf the second highest producer, *Acer rubrum* (red maple), which has produced 833.69 kg of oxygen from the 91 individuals of that species in the planting record. However, in 2018 the planting record was also responsible for emitting an estimated 39.22 kg of volatile organic compounds (29.32 kg isoprene, 9.904 kg monoterpenes). Thirty eight percent of the planting record's total VOC emissions come from two species in particular: *Platanus acerifolia* (London plane tree) and *Quercus rubra* (red oak).

Unlike their marginal effects on oxygen levels, urban trees are capable of intercepting precipitation at a dramatic rate. Surface rainwater runoff can be mitigated as a result of root systems infiltrating the soil and storing water within the tree pit. Due to the decreased area of impervious surface, an estimated 150.1 cubic meters of water is avoided each year. The *Platanus acerifolia* (London plane tree) was the most productive followed by *Acer ginnala* (amur maple).

Based on the estimates provided, some correlative effects can be given in order to contextualize the information provided. In one year, it is estimated that the UC Green planting record is responsible for storing the carbon emitted from 84 cars or 34 single family homes, the sulfur dioxide emitted from 55 cars, and the nitrogen dioxide of three cars or a family's home.

In regard to public health, the planting record is notable primarily for its air pollution removal. Although some volatile organic compounds are emitted by the trees, it has been shown that increased canopy cover leads to lower ozone formation rates overall (Dwyer et al., 2000), but some debate about this subject is ongoing between urban ecologists, urban foresters, and epidemiologists. The UC Green planting record was responsible for removing an estimated 100.7 kgs of pollution from the atmosphere every year in the forms of O_3, PM 2.5, CO, NO_2, and SO_2. The most significant amount was for ozone, and then particulate matter smaller than 2.5 microns.

The economic developments that are related to the UC Green planting record either come directly through the environmental benefits it provides, or indirectly through the associated industries that it enables. Directly the trees in UC Green's planting record are responsible for $959 per year of carbon sequestration, $354 per year of avoided rainwater runoff, and $2.31 thousand per year of pollution removed. The structural value of the planting record entirely is

$695 thousand with *Platanus acerifolia* (London plane tree), *Syringa reticulata* (Japanese tree lilac), and *Gleditsia triacanthos* (Honey locust) being the three species with the greatest individual structural values. The structural value of the carbon stored is $20.2 thousand. Indirectly, there are, at minimum, two small tree care businesses in the UC Green geographic zone and many others in the nearby suburbs that profit from working on these trees and others. Artistic products have been made from UC Green's felled trees, and frequently, donations are made by homeowners out of gratefulness for their newly planted tree. Except for these donations, UC Green is not the beneficiary of any of these economic developments, they are likely only realized by the municipal systems like wastewater treatment facilities in that they do not have to engage the load that the planting record offset. Other indirect economic effects that were not calculated include the amount of energy costs mitigated for homeowners and commercial establishments, the increase of consumer time spent in commercial districts due to perceived walkability, or the potential for UC Green to convert felled trees into mulch and negate some of their operational costs, among others.

Finally, it should be stated that although the estimates of the ecosystem services that UC Green's living trees contributed were calculated, they do not represent a complete perspective about the ecosystem disservices that are also implicitly included as well. This information is outside the scope of this case study and thus was neither calculated nor included in these results.

DISCUSSION

Advantages and limitations of the remote inventory method

This case study was undertaken in pursuit of testing a remote method of data collection for tree inventorying while simultaneously determining the characteristics of UC Green's planting records. What follows will be a discussion of those results, some other related subjects, the presentation of realistic goals for UC Green, and a reflective review of this case study.

The advantages of the remote method extend well beyond the fact that field work was not required. First, there were not external obstructions to data collection such as weather conditions, time of day, or participant availability. Furthermore, other than the software, no additional equipment was required. This benefits a planting program in a number of ways. Primarily, it is counter-intuitive to use a car to collect data about how trees are able to reduce pollution in the air among other ecosystem services. Additionally, recognizing that the space between the two most distant trees in the planting record is over three and a half miles, the benefit of using a computer becomes clear. Additionally, even if the data collection load was split between groups of people, they would still require measuring tapes, data collection materials, and based on their expertise levels, dichotomous keys in order to make accurate species identifications. Apart from equipment, transportation, and external obstructions, field collection is also at a disadvantage in that it requires an additional stage of data transcription. The primary reason that both UC Green and the Pennsylvania Horticulture Society sought out a new data management system was that their existing method required data to be collected, and then input manually into another database. Within the remote collection approach, the tool's native mechanisms format the data at the moment it is recorded, which reduces transcription errors, avoids data loss due to bad handwriting, and decreases redundant work. However, the Urban Forest Cloud upload template and the Treetective export format do not directly correlate, so there is a still a need for some slight data transcription, but this issue could be rectified in future versions of the products.

This case study cannot determine which approach could claim advantage in terms of time efficiency, but the remote tool is likely the quicker of the two. Although field data collection can be done by multiple people at the same time, the remote data collection approach could also hypothetically be done by multiple users on multiple devices. If one set of planting records were inventoried twice, using each approach, a determination could be made about which was more efficient. Although the rough estimate of four months was provided above in methods, there is no field based inventory that recorded a collection rate for comparison. Nonetheless, when considering the two most obvious benefits of each method, the remote approach seems to emerge as the more efficient. First, in the field there is more information available to make a species determination simply due to the fact that the tree is entirely physically present. Remotely, there is simply not as much information in the images, which can delay identification. But, the gains that the field approach might make resulting from that likely do not offset the considerable difference in the time it takes to switch between trees for each method. Treetective is able to respond to the user's prompt to locate the next tree in a fraction of a second whereas sometimes participants are required to travel blocks or miles to locate the next tree site.

It is also important to indicate a major disadvantage of the remote approach. Without doubt the most egregious disadvantage is the amount of information available to make a species identification. Google Street View images only offer a few visual perspectives on each tree. As a result of this there are often only a few leaves or branches that are visible that have enough detail to accurately determine the species and genus. Furthermore, images of the trees are sometimes blurred or obscured by other objects like cars, signs, or buildings. In this case study there was a heavy reliance on more obvious tree features such as growth habit, branch arrangement, bark, and leaf shape, instead of smaller scale features like leaf margins, venation, buds, or flowers.

Recommendations for Treetective

Although Treetective embodies an innovative remote data collection tool for trunk diameter and location, there are other features that could also be added to improve ease of use, accuracy, and range of variables collected. At this point, Treetective relies entirely on the user to make a determination about species and genus based on their own arboriculture knowledge. If there were a dichotomous key available within the tool itself, it would open up the pool of potential users to include those with limited expertise. Beyond that, there is potential for machine learning utilities to suggest a species based on leaf shape or color to aid the user in accurate identification. Furthermore, since there have been multiple instances of Google Maps collecting Street View images for the majority of the world's streets, Treetective could also be capable of showing images of trees at different stages in their lives. By allowing users to view trees from different times more information becomes available to the user, which increases the likelihood of an accurate identification. Chronological images would also be useful in order to confirm replacements and removals. Finally, since Google Maps estimates the size of a tree's crown at the lowest level of bird's eye view above Street View, another measurement tool could be added to potentially collect estimated tree height, crown circumference, and proximity to buildings.

As it relates to the mission of UC Green, and ongoing growth monitoring, Treetective is likely an extremely useful tool for multiple purposes. As has been stated, having collected the baseline inventory, the planting record should continue to be updated every few years with new data about growth and mortality rates. If this were done by volunteers using Treetective, two positive outcomes could be achieved: the collection of more data for analysis and programmatic assessment, and perhaps more importantly, the education of volunteers through engagement.

Recommendations for UC Green

On the subject of volunteers, not only does the gross number matter for environmental awareness, but which particular volunteers that are engaged also deserves careful study. By reviewing an overlay of the planting record on top of census tract data, a planting program is able to identify which areas of their zone should be prioritized for plantings based on tree canopy, income, crime, and demographic data. Knowing which tracts have low percentages of tree cover, and high percentages of poverty and crime, planting programs can focus their efforts where the beneficial aspects of tree cover will be most impactful. Although a review of this data was not a part of this case study, as can be seen in Figure 6, census tracts with greatest priority have been identified through a collaboration between the Pennsylvania Horticulture Society, the Philadelphia Department of Parks & Recreation, and Open Data Philly using ESRI mapping technology and data from the Census Bureau. In Figure 6 the areas with green or yellow streets are low priority, conversely those in red are high priority. Although UC Green was not originally planting in areas outside of the University City District, as has been stated, in recent years many trees have been planted throughout West Philadelphia. Not only should this trend continue, but it is incumbent on UC Green and any planting program staff to recognize tracts of greatest priority, engage their residents, and plant trees alongside them. The benefits of a diverse network of volunteers extends well beyond the environmental and public health benefits of a high canopy cover percentage. The fabric of society itself is capable of being shifted towards a more equitable and just world, where everyone is able to learn and grow within a tree lined community.

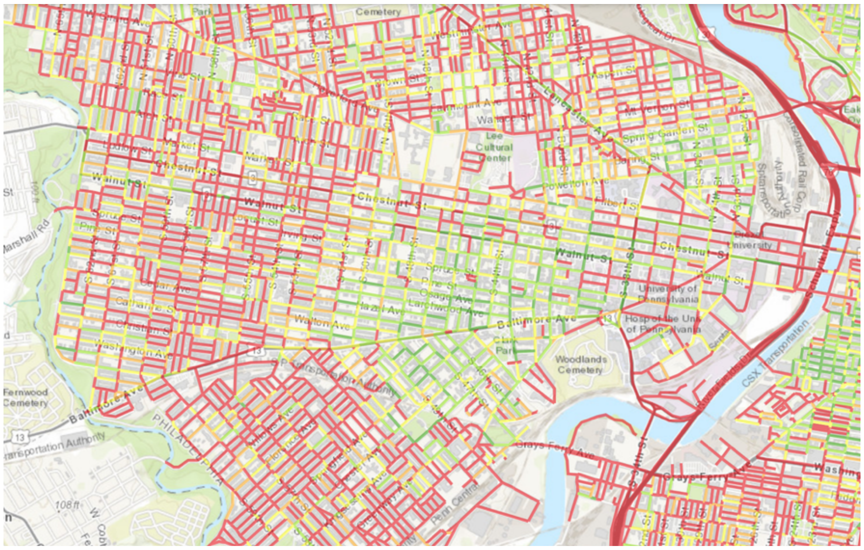

Figure 6. Census tract prioritization map (PHS et al., 2019)

In the areas that UC Green has historically planted trees, there are substantial ecosystem services that are being enjoyed by residents every day. Distinct from all the ecosystem services mentioned in the results, one of the benefits of urban forests that has not been discussed yet is the mitigation of the heat island effect. West Philadelphia is no exception to the fact that extensive tree coverage ameliorates the microclimate of a neighborhood due to the trees' environmental benefits (Georgi et al., 2006). By processing images derived from the Normalized Difference Vegetation Index, Steif (2016) noticed that West Philadelphia, and particularly its areas with dense canopy cover, were much cooler during the hottest parts of the summer. Although Steif (2016) and Figure 7 suggest a correlation between the temperature of a neighborhood and its percentage of tree canopy, more analysis is needed to prove causality. Despite this lack of demonstrable causation, UC Green's planting record at least seems to contribute to temperature reduction and the subsequent decrease in heat-related medical issues for its community.

Of the many variables collected during the aggregation phase of processing, one was the size of the pit that the trees are planted in. This is information recorded by contractors who were hired to make the pavement cut. As a result of this, UC Green is able to demonstrate the amount of sidewalk pavement that it has had removed during the course of its planting history. Since pit sizes vary, and not all records had pit size recorded, an average was taken and found to be 16.5 ft^2, making the estimated amount removed to be 24,503 ft^2. Considering that an American football field is 6,400 yd^2, UC Green has removed the equivalent of 3.82 during its history.

Figure 7. West Philadelphia heat index map subsection (Stief, 2016)

In an attempt to continue supporting UC Green in the development of their urban forest planting record, some goals will be suggested based on the data collected and analyzed.

Principally, the target number of trees planted each season, based on the historic totals, should be 46 planted per season and 92 per year, with a standard deviation of 121.72 trees. Recognizing that organizational changes will determine the availability of funding and that the potential to meet this target relies on the continuing support of the volunteer base, this is suggested to both increase impact output and remain within the realistic bounds of capacity.

Secondly, the number of volunteers engaged, should be 50 per season and 100 per year, with a standard deviation of 48.51 volunteers. This, too, recognizes that external forces largely dictate the availability of volunteers, but considering the variables, this target is suggested.

Thirdly, inventorying and monitoring of the planting record should be attempted, if not completed, every three years. UC Green has been operating for twenty years and only as of this case study has the full planting record been inventoried. With the support of the Pennsylvania

Horticulture Society's Tree Checkers program, this is possible every year for newly planted trees, but additional work internally can be done to monitor the historic planting record as well.

Fourth, UC Green should work to expand the scope of their tree planting program in order to emphasize planting efforts in the areas that have the greatest priority as indicated by Figure 6. It is not enough to plant in areas that have relatively high incomes and low crime statistics. In order to serve the entire West Philadelphia area equitably, divergence from the norm is suggested in terms of application outreach, volunteer engagement, and tree planting efforts.

Fifth and finally, UC Green should make efforts to provide support to other tree planting programs in Philadelphia who do not have the advantages that it does. Administrative guidance, data management help, volunteer lending, and the sharing of best practices are all suggested.

Reflections on the research process

In closing, a reflective review of the process by which this case study was completed will be given as well as a summary of its limitations, and lessons learned while completing it. Generally, this process was time-consuming, repetitive, and largely tedious. That being said, the benefits that were derived from it make the entire process worthwhile in abundant measure.

The initial stages of aggregation and validation were extremely difficult due to the variety of source materials and disorganization of the filing systems. The notes left by the former executive director were extremely helpful, but the state of the physical documents at the UC Green office left much to be desired. In the same sense, the digital files were also distinctly out of order, which made the process of aggregation all the more difficult.

During the collection phase at Azavea, there were other types of setbacks, but also great opportunities for collaboration and creativity. Unexpectedly, there was an issue of physical pain resulting from the repetitive motions required for the data collection task itself. Wrist and joint pain became enough of an encumbrance that time had to be taken off in order to recover and be able to continue with the work. Apart from that, the data collection phase was distinctly intriguing in that the developers of Treetective were available to receive comments and respond to complaints directly and efficiently. Whether about the user interface, functionality, or overall design, the process of collaborating creatively was unique as well as intellectually inspiring.

The follow up phases of implementation and analysis were perfunctory at best and at worst, cursory. Formatting and inputting data into applications for processing requires little to no in depth thinking. This phase took the least amount of time of any, but were nonetheless valued.

Finally, like the earlier phases, drafting this case study report was an exercise in patience and due diligence. Measured statements and careful review were largely its guiding themes.

Some of the lessons that were learned about this process have been detailed in other sections, but some of the more notable ones include: keeping metadata notes about source files locations, the value of corroborating documents to verify information, the difficulty of describing processes so that others might replicate them, and the implicit limitations of a single researcher's capacity as a result of time. These also speak somewhat to the limitations of the study itself.

Since there were abundant documents, the scope was limited to the trees planted via the coalition supply chain. Initially, this study was intended to develop a process by which communication with homeowners about their trees could be established and provide a mechanism for UC Green to decentralize data collection, but this was not undertaken due to data constraints. Additionally, this study was limited by the desired analysis. Only the three core variables were processed, but many, many more details could have been included for analysis. The last limitation was the author's skills. They were grown during instead of before the study.

CONCLUSION

Caretakers of the urban forest are like parents in a sense. They have cultivated and nurtured their children for years, and only ask that they be themselves in return. Members of the UC Green community have been doing this careful work for twenty years now, and this case study is an attempt to recognize and celebrate their successes doing it. Their methods have developed a diverse and productive family, of both trees and humans, who are all working simultaneously to grow themselves amidst the world. But, a parent's work never ceases; unconditional love requires labor. Given that new technology brings new opportunities, parents have a duty to seek out the tools that can ensure growth for their children, and master them. Using the described tools for growth, parents of the urban forest can labor to sustain it beyond themselves, and in doing so, find meaning in their lives. There is a quotation that is often misattributed to the ancient Greeks, and Ronald Reagan, but as Roger Pearse pointed out in 2017, it is likely from an old Quaker text on morality saying simply that "A man has made at least a start on discovering the meaning of human life when he plants shade trees under which he knows full well he will never sit" (Trueblood, 1951). Working to expand and sustain UC Green's family is a labor based in love, and a step forward in pursuit of the meaning of all of our lives.

ACKNOWLEDGEMENTS

Many thanks to Dr. Sally Willig at the University of Pennsylvania and Dr. Lara Roman at the USDA Forest Service for reading this capstone and providing many insightful comments; Robert Cheetham, Deborah Boyer and the Urban Apps team at Azavea; Jason Henning at the Davey Institute; Dana Dentice, Mindy Maslin, and the PHS Tree Tenders staff; Ed Datz, Kiasha Huling, Christina Costanzo, all of the UC Green volunteers, and Winnie Harris, whose work legacy represents the majority of this data; my friends who oblige me with conversations about trees; my mother and sister for their tireless encouragement and joy & my father, for everything else.

APPENDIX

Species and genus, common name, species code, count, and percentage of planting record

Acer campestre	Hedge maple	ACCA	27	2.192%
Acer x freemanii	Freeman maple	ACFR	25	2.029%
Acer ginnala	Amur maple	ACGI	38	3.084%
Acer griseum	Paperbark maple	ACGR	10	0.812%
Acer miyabei	Miyabe's Maple	ACMI1	1	0.081%
Acacia microbotrya	Manna Wattle	ACMI2	1	0.081%
Acer platanoides	Norway maple	ACPL	13	1.055%
Acer platanoides	Crimson king	ACPLCK	1	0.081%
Acer rubrum	Red maple	ACRU	91	7.386%
Acer saccharinum	Silver maple	ACSA1	12	0.974%
Acer saccharum	Sugar maple	ACSA2	39	3.166%
Acer tataricum	Tatar maple	ACTA	15	1.218%
Acer truncatum	Purple blow maple	ACTR	5	0.406%
Amelanchier x grandiflora	Apple serviceberry	AMGR	25	2.029%
Amelanchier laevis	Smooth service berry	AMLA	16	1.299%
Betula nigra	River birch	BENI	8	0.649%
Carpinus betulus	European hornbeam	CABE	30	2.435%
Carpinus caroliniana	American hornbeam	CACA	25	2.029%
Cercis canadensis	Eastern redbud	CECA	41	3.328%
Cercidiphyllum japonicum	Katsura tree	CEJA	13	1.055%
Celtis occidentalis	Northern hackberry	CEOC	13	1.055%
Chionanthus virginicus	Fringe tree	CHVI	1	0.081%
Cladrastis kentukea	Yellowwood	CLLU	41	3.328%
Corylus colurna	Turkish hazelnut	COCO2	8	0.649%
Cornus florida	Flowering dogwood	COFL	10	0.812%
Cornus kousa	Kousa dogwood	COKO	2	0.162%
Cornus mas	Cornelian cherry	COMA	7	0.568%
Crataegus crus-galli	Cockspur hawthorn	CRCR	3	0.244%
Crataegus mollis	Downy hawthorn	CRMO	2	0.162%
Crataegus viridis	Green hawthorn	CRVI	17	1.380%
Fraxinus pennsylvanica	Green ash	FRPE	2	0.162%
Ginkgo biloba	Ginkgo	GIBI	15	1.218%
Gleditsia triacanthos	Honeylocust	GLTR	79	6.412%
Gymnocladus dioicus	Kentucky coffeetree	GYDI	2	0.162%
Halesia carolina	Snowdrop tree	HACA	2	0.162%
Liquidambar styraciflua	Sweetgum	LIST	3	0.244%
Malus	apple spp	MA2	38	3.084%
Maackia amurensis	Amur maackia	MAAM9	11	0.893%
Ostrya virginiana	Eastern hophornbeam	OSVI	8	0.649%
Phellodendron amurense	Amur corktree	PHAM	2	0.162%
Platanus hybrida	London planetree	PLAC	39	3.166%
Platanus x acerifolia	London plane	PLAC1	2	0.162%
Prunus	plum spp	PR	9	0.731%

Prunus avium	Sweet cherry	PRAV	7	0.568%
Prunus cerasifera	Cherry plum	PRCE	18	1.461%
Prunus incisa	Fuji Cherry	PRIN1	3	0.244%
Prunus padus	European bird cherry	PRPA	4	0.325%
Prunus sargentii	Sargent cherry	PRSA	59	4.789%
Prunus serrulata	Japanese cherry	PRSE2	13	1.055%
Prunus subhirtella	Higan cherry	PRSU	48	3.896%
Prunus virginiana	Common chokecherry	PRVI	35	2.841%
Prunus virginiana 'Shubert'	Shubert chokecherry	PRVISH	7	0.568%
Pyrus calleryana	Callery pear	PYCA	13	1.055%
Quercus	oak spp	QU	1	0.081%
Quercus acutissima	Sawtooth oak	QUAC	12	0.974%
Quercus alba	White oak	QUAL	11	0.893%
Quercus bicolor	Swamp white oak	QUBI	4	0.325%
Quercus coccinea	Scarlet oak	QUCO	2	0.162%
Quercus palustris	Pin oak	QUPA	9	0.731%
Quercus robur	English oak	QURO	3	0.244%
Quercus rubra	Northern red oak	QURU	29	2.354%
Robinia pseudoacacia	Black locust	ROPS	4	0.325%
Styrax japonicus	Japanese snowbell	STJA	1	0.081%
Syringa reticulata	Japanese tree lilac	SYRE	125	10.146%
Tilia americana	American basswood	TIAM	2	0.162%
Tilia cordata	Littleleaf linden	TICO	14	1.136%
Tilia mongolica	Mongolian lime	TIMO	4	0.325%
Tilia tomentosa	Silver linden	TITO	5	0.406%
Ulmus americana	American elm	ULAM	4	0.325%
Ulmus parvifolia	Chinese elm	ULPA	1	0.081%
Ulmus	elm spp	ULS	14	1.136%
Zelkova serrata	Japanese zelkova	ZESE	28	2.273%

Categories used in data collection table

Planted?
Tree_ID
Planting Program
Season_Planted
Season_Requested
Replacement
Address #
Street
Address_#_GIS
GIS_Address
SiteID
Location_Notes
TT_App Notes
Species_fullname
Species_(Latin)
Cultivar_Common
City
Zipcode
Owner Phone
Owner_Email
Owner_Mailing
PPR_Approval
Inspector
Insp_Date
Nursery Stock
Pit_Size
Pit Maintenance
PHS_Program
Mortality_Status
Caretaker_Name
Caretaker_Phone
Caretaker_Email
Volunteers_#
DBH
DBH_height
DBH_date
Maintenance
Maintenance_date
Metadata_source

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