A STREET TREE INVENTORY FOR MASSACHUSETTS USING A GEOGRAPHIC INFORMATION SYSTEM

by David W. Goodwin

Abstract. The creation of a street tree inventory using Geographic Information System (GIS) software can greatly enhance municipal tree management. Many different techniques were explored in an effort to map tree locations efficiently and accurately, including aerial photo interpretation, Global Positioning Systems (GPS), surveying techniques, and tree placement on existing base maps. Additionally, several different types of basemaps were tested to optimize accurate cartographic transfer of tree locations. Detailed data about tree attributes were collected in the field using a portable, pre-programmed computer so that these data would be compatible with a GIS. The spatial tree location data were joined with the tree attribute data to produce a fully functional spatial database for street tree management purposes. Based upon two case studies, the advantages and disadvantages of each project phase are discussed and qualified.

An inventory of street trees is important for effective municipal tree management. This effort is greatly enhanced by using a Geographic Information System (GIS) to map these tree locations. Tree location and tree attributes are valuable elements of a municipal tree management system. By creating the tree data in a GIS, users have access to other digital data that can be used in conjunction with the tree database. These elements used together help to make municipal tree management more thorough and cost effective.

Communities that would like to create a street tree inventory have several choices to make before deciding how to approach this type of project. The availability of certain types of resources will largely determine the techniques that are the most effective for tree mapping. The type, scale, content, and accuracy of an available base map is the first assessment that needs to be made. This will determine the degree of ease or difficulty in all subsequent steps. The method of locating individual trees is an important decision. Will this be done from aerial photographs or on the ground? If aerial photographs will be used, what type and scale are the most appropriate? If tree location information is to be gathered in the field, what techniques are accurate and time efficient? How will individual tree attributes be collected? What attributes are important to the town as the foundation of the tree management program? It will probably be necessary to visit each tree in order to obtain useful information.

This paper will summarize approaches that have been tried in order to create a street tree inventory. Successes and failures will be outlined to help communities that would like to create an accurate and fully functioning street tree digital database with GIS and wish to make informed decisions.

Base Map

It is necessary to determine what type of base map will used as the foundation for the street tree inventory. The choices include (but are not limited to) parcel maps, orthophotoquad maps, topographic maps, street layout maps, utility or facility maps, and thematic maps. The important qualities of these maps are scale, accuracy, geo-referencing, and the types of features that are represented on them. To ensure town-wide compatibility, it is important that there is complete coverage of the entire area to be mapped using the same type of base map.

Scale: Trees are small features on most maps. The scale of the base map needs to be large enough to allow the user to distinguish one tree from another. A US Geological Survey (USGS) topographic map at 1:24,000 (1" = 1,000') is most likely too small a scale for this type of mapping. Maps of building sites at 1"= 20' (1:240) are most likely at too large a scale. However, a parcel map at 1"= 100' or 200' (1:1,200 or 1:2,400) is just about right for urban tree mapping. It is large enough to show a neighborhood yet small enough to show individual tree locations.

Accuracy: Accuracy can be measured in terms of a feature's absolute accuracy (a measure of its actual point on the face of the earth) or its relative accuracy (a measure of its location relative to other features on the map). There is concern for both types of accuracy in a base map because they determine how useful the tree location data are when compared to other data sources. Accuracy is usually measured by parameters established by the US National Map Accuracy Standards. As a very general rule, maps produced by the federal and state governments, surveyors, and most private mapping and engineering companies have acceptable accuracy while maps produced without any surveying or geodetic control (e.g., maps produced from uncontrolled or unrectified aerial photographs) are probably not acceptable. Most maps will state on them that they meet National Map Accuracy Standards if indeed they do.

Parcel maps usually fall somewhere between these two extremes. Past experience indicates that it is often a challenge to know exactly how a town's parcel maps were created. Some are based on detailed surveys, some based on historical unrectified aerial photographs, some based on historic street layout maps, some based on an individual's idea of what they think the parcel boundaries should look like, and a few are based on modern, aerial photographs used in a three dimensional analytical stereoplotter. This instrument compensates for the elevational change in the landscape and produces a rectified map. Often, as a town grows over time, a combination of techniques are used to create the parcel map. This is not to discourage the use of parcel maps because they are often quite useful maps on which to base a street tree inventory.

Geo-referencing: Accurate geo-referencing of a base map is necessary to input the tree data into the GIS. Geo-referencing refers to a Cartesian coordinate system that relates points on the map to corresponding points on the earth. These coordinates may be latitude and longitudinal degrees, minutes and seconds, state plane feet, universal transverse mercator meters, or one of many other types of systems. There need to be well defined points on each map sheet that indicate what coordinate value that point has in the real world. Without this information, it is impossible to use the tree data with any other information that was created from other map sources.

Map features: Since the accurate placement of a tree depends largely on its position relative to other features, a base map should contain a lot of these other features. These include roads (centerlines and edge of pavement), road names, sidewalks, building shapes or outlines (commonly called building footprints), water bodies, streams and rivers, utility poles, fire hydrants, manhole and sewer covers, railroad lines, survey points, landmarks, geodetic control points, shorelines, and other natural and cultural features.

Generally, no base map will have all of these features, nor is it necessary. Often, a line and symbol map such as a parcel map, a utility map, or a USGS topographic map portrays enough information to pinpoint a tree location. A photographic base map such as an orthophotoquad may also be sufficient, especially if certain cartographic additions are made such as street names, town boundaries and hydrographic names. The photograph, in this instance, supplies many distinguishable map features that would be nearly impossible to map on a line and symbol map.

Tree Location

There are numerous techniques available to efficiently and accurately map tree locations, including aerial photo interpretation, Global Positioning Systems (GPS), surveying techniques, and using existing maps for tree placement. Only aerial photo interpretation allows for tree location mapping remotely, each of the other techniques require an on-the-ground inventory. Each technique has advantages and disadvantages which will be discussed below.

Aerial photograph interpretation: Aerial photography can be purchased for most communities from the USGS, state agencies, or private companies. Several parameters will affect their utility, such as scale, type of film (black and white, color, color infrared). time of year (leaf-on, leaf-off), and the technological sophistication that was used to capture the photography.

Scale will determine photographic resolution and this determines how accurately tree locations can be defined. The type of film determines the amount of contrast between the tree and its surroundings. Generally, black and white has the least contrast while color infrared has the most contrast. Leaf-on film will make almost every tree noticeable but several trees growing close together may have crowns that are merged together and therefore inseparable. Leaf-off film will allow for crown separation (except for evergreens) but will make the hardwoods more difficult to identify. Shadows, from various structures and other trees, will often obscure some trees, but this is more of a factor with hardwood trees on leaf-on photography due to the shape of their crowns. A lower sun angle in the early spring and especially in the fall are important considerations. Most modern photography has been processed to eliminate much of the distortion inherent in the photographic process.

Global Positioning System: GPS technology is very appealing for tree location mapping. In theory, the user stands at the tree to be mapped with a GPS unit, records a lot of point location information by tracking satellite signals for each tree, post processes these data with other data gathered at a base station, and produces a final point location for each tree visited during that day's session. Depending upon the accuracy of the GPS unit used, the number of points gathered for each tree, the constellation of satellites in the sky during field collection, and the availability of good base station data, tree locations can be within 2 to 5 meter accuracy for a typical GPS unit or sub meter accuracy with a high accuracy GPS unit.

Surveying: Another method for identifying tree locations is with a surveying approach. In order for this to work, a course is started from a known point or benchmark. Sightings are taken from this point to as many street-side trees as are visible, measuring distances and bearings with a transit and a rodman holding a leveling or transit rod (or a more sophisticated instrument like a "Total Station" that uses infrared light to measure distances and a computer to automatically record each reading). By moving to one of the trees already surveyed, the process is continued by building a network of tree locations.

Use of Existing Maps: Another method for mapping tree locations is to take advantage of existing maps, whether or not they meet the requirements of the base map as detailed above. These could be any of the maps described under the **Base Map** section, although there are many other types of maps available that have not been mentioned. The important qualities of these maps is that they can be taken into the field, people can identify their location, can locate a tree, and mark its location on the map. The map, therefore, needs to have enough reference features in order to accurately place the tree location on it relative to these other features.

Tree Attribute Collection

Unless high quality aerial photographs are available at a large scale and are interpreted by someone knowledgeable of species identification, even basic tree attributes will need to be collected in the field. By working with urban forestry professionals, it was decided that the most useful attributes for the development of useful management strategies are a unique tree code, species, diameter at breast height (dbh), condition, root zone cover, percent impervious material over root zone, weak crotch, overhead wires, dead wood in crown, cavity in trunk or main leader, street tree, park tree, management need, safety pruning, lifting, and crown reduction. This established the inventory criteria for this study.

These attributes clearly require on-site tree examination. Since integration with GIS is the ultimate goal, it is necessary to record this information on a computer or data logger, or write them down in the field and enter them in manually onto a computer at a later date. Any GIS can integrate computer text files with the spatial, digital tree location information. The best solution is to have a pre-programmed computer or data logger in the field to make this step as efficient as possible.

Integration

At this point, all the elements are in place to integrate tree locations with the tree attribute database. The method chosen to map tree locations will determine how to integrate all this information in a GIS.

If aerial photographs were used to identify tree locations, it will be necessary to transfer them to whatever base map is used. Once transferred, the tree point locations can be digitized with the GIS software. This is where it is critical to have a base map with an acceptable coordinate system.

If GPS or Total Station surveying techniques were used, the transfer and digitizing phases are not necessary as the tree location data can be brought directly into the GIS via computer ASCII files. For traditional surveying techniques, the gathered data would need to be entered into some type of computer database before final integration could be done.

If existing maps are used to plot tree locations in the field, it will be necessary to follow the transfer and digitizing steps used for aerial photography unless they are already accurate and contain geo-referencing. For aerial photography and existing maps that do not have a coordinate system grid on them, the transfer to the base map needs to be done in such a way so as to compensate for the distortion inherent of both of these sources. Ideally, a cartographic instrument such as a transfer scope should be used, but photo reduction or enlargement to match scales may work well enough. By aligning both sources, one on top of the other on a light table, it may be possible to transfer the tree location to its proper location on the base map. As another option, it may be possible to simply extrapolate the location from field map to base map by approximating its position relative to other features such as building footprints.

A critical element to digitizing tree locations is to give each tree the same identification number as the number used in the field for its data. Once the tree locations are in a digital form, the spatial tree location database can be joined or merged with the attribute database by using this unique identification number.

Case Studies

Working with professionals and hundreds of volunteers, a street tree inventory was conducted in two towns to test these procedures. Brookline, Massachusetts is a heavily urbanized town that is surrounded by Boston on three sides yet has a number of suburban neighborhoods. The other community chosen was the downtown (Metro Center) area of Springfield, Massachusetts, a very urban area. These two communities were chosen because a variety of base maps, aerial photographs, materials and resources were available to test.

Brookline. It was very difficult not to use Brookline for a case study. Not only were all different types of aerial photographs, orthophotoquads, and digital utility maps available, but they have a long history and present commitment to urban forestry. In addition, they have their own functional GIS so they could immediately use the database that was to be created. However, it took many attempts before the best approach was discovered that would create a street tree inventory. Timing and availability of various map resources required cooperation with town officials and others.

Initially, it was expected to use 1:12,000 scale color infrared aerial photographs taken during the spring (leaf-off) to locate the trees, a 1:5,000 scale analog orthophotoquad as a base map, and a professional arborist to create the tree attribute database. As it turned out, the final methodology was completely different than this.

The photographs were generally acceptable. By using overlapping photographs on a stereoscope, neighborhoods and trees could be seen in three dimensions to identify street-side tree locations. However, since these photos were leaf-off, some hardwood trees that were in shadows from buildings could not be seen as well as other large leafless trees and some evergreens. However, the time to locate the trees on the photographs was measured in days, not the weeks required to do it on the ground.

Tree locations were transferred to copies of 1:5,000 scale orthophotoquads. This process was fairly easy because features visible on the photo were generally visible on the orthophotoquad. By adjusting for scale and aligning features with a transfer scope, a direct transfer from photograph to orthophotoquad could be made. A copy of this map with tree locations was given to a municipal arborist who then took it into the field to assess the accuracy of tree placements and errors of omission and commission made by photointerpretation. His report back was not positive.

Since the orthophotoquad lacked most road names, it was very difficult to know where he was at any given time. Once this was corrected by adding street names to the orthophotoquad, he still had difficulty knowing which tree he was actually looking at. The resolution of the orthophotoquad was not sharp enough to identify discreet building outlines that were valuable for position reference.

To modify this process, he was sent out into the field with a map showing just streets, street names and tree locations (the orthophotoquads may have been more confusing than useful). Without additional references, this process was also a failure. Building footprints for a sample area were digitized, joined with the streets, street names and tree locations. Again, he went out into the field, this time with qualified success.

From this experience two things were learned. First, streets, street names, building footprints, and in some situations, house addresses are necessary to know which tree was being visited. Secondly, trees with a dbh of less than 4 inches were consistently missed. When coupled with missing trees in shadows, it was concluded that good photography was not good enough.

Brookline has approximately 9,000 buildings and it was not practical to digitize all of them. There were three options at this point, one was to search out larger scale aerial photographs, the second option was to track down existing digital building footprints, and the third option was to find a different way to map tree locations. All three of these options were eventually explored.

A private aerial photography company was contacted and sample photographs of Brookline at 1:5,760 (1"=480') were obtained. These photographs were photointerpreted and compared to the 1:12,000 scale photos already interpreted. The results of this were better but the same problems existed as with the other photographs, namely, trees were missed that were in shadows and under about 4" dbh. Photographs at a scale larger than 1:5,760 were not located; however, other smaller scale photographs were tested with similar results.

A fortuitous event made option 2 possible. From a conversation with the Boston Edison Company, a large electric utility supplier in the greater Boston area, it was discovered that they were in the process of creating a very detailed digital data base for their member communities. Brookline was going to be mapped for 23 different data layers, including road centers, road names, road edges, building footprints, and sidewalks. Boston Edison agreed to allow access to this database by licensing it for the purposes of this project. In return, they were provided with the digital tree locations. Figure 1 displays a sample of this database.

Since the Boston Edison database would not be available for approximately one year from the time this phase of the project was reached, it was decided to explore the third option - a completely different approach to urban tree mapping. With cooperation from University of Massachusetts Urban Foresters, a system that complemented their use of volunteers to collect tree attribute data was designed. By sending the volunteers out in the field with 1" =125' (1:1,500) scale parcel maps that had streets, street names, building footprints and house numbers, they were able to know where they were, add tree locations to these maps relative to other features, assign a unique number to each tree, and enter all the attributes for each tree using a computer program that was written specifically for this project. Figure 2 shows a copy of a Brookline field map prepared by one of the many volunteers.

Once the Boston Edison digital database was completed, it was clear that they would make excellent base maps for the Brookline project. With the volunteer enhanced maps showing tree locations and the tree attribute database in hand, it was possible to easily put them together. A transfer scope was used to transfer tree locations accurately from parcel map to base map. Not only was the tree inventory now complete, but it was entirely consistent with all 23 data layers created by Boston Edison. Figure 3 shows the completed tree inventory integrated with the Boston

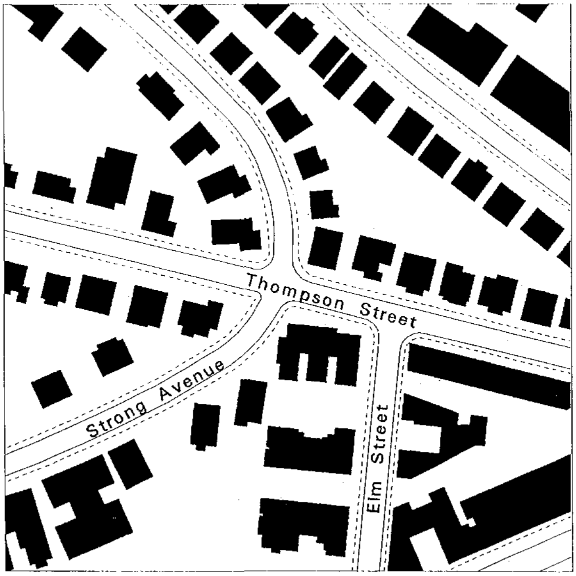

Figure 1. Sample Boston Edison digital database in Brookline showing street edges, street names, backs of sidewalks, and building footprints.

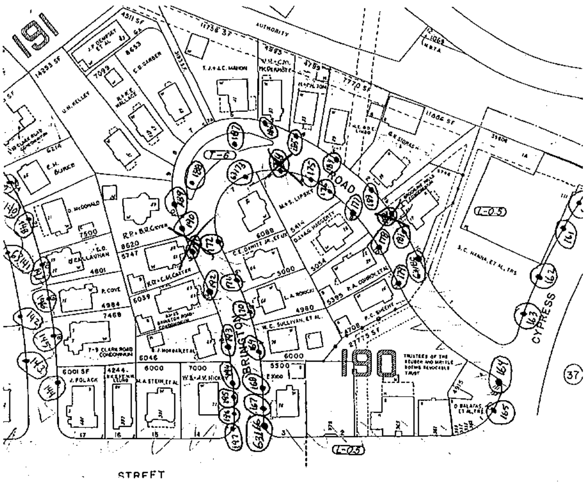

Figure 2. Representative field sheet from Brookline.

Edison database for a sample area, and Table 1 is a list of attributes collected for these trees.

Springfield. These techniques were then tested in another community that had source materials different from those in Brookline. A town was sought that either had larger scale photography or digital parcel maps with building footprints. It also was necessary to find a town that had an acceptable base map. The western Massachusetts city of Springfield had 1:5,000 scale black and white

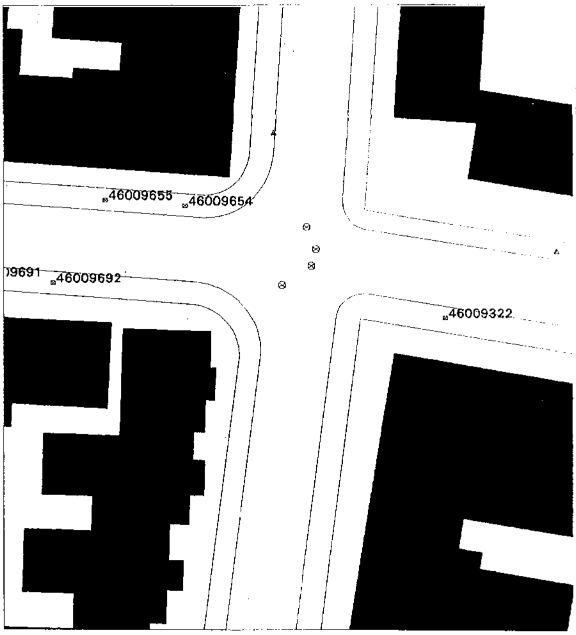

Figure 3. Digitized tree locations integrated with Boston Edison database in Brookline.

Table 1. Sample list of tree attributes collected in the field by volunteers.

treeid	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*	15*
46009322	fa,	36,	g,	g,	2,	n,	y,	n,	n,	y,	y,	p,	y,	n,	n
46009654	ap,	11,	g,	g,	2,	n,	n,	y,	n,	y,	y,	p,	y,	n,	y
46009655	ap,	32,	g,	g,	2,	y,	n,	y,	n,	y,	y,	p,	y,	y,	n
46009691	am,	28,	f,	c,	4,	n,	n,	y,	y,	y,	n,	c			
46009692	ar,	30,	g,	c,	3,	n,	y,	n,	n,	y,	n,	p,	n,	n,	n

1	tree species code
2	dbh in inches
3	present condition
4	predominant root zone cover
5	impervious percentage over root zone
6	weak crotch
7	overhead wires
8	dead wood in crown
9	cavity in trunk
10	street tree
11	park tree
12	management need
13	safety pruning
14	needs lifting
15	needs crown reduction

aerial photographs, good parcel maps, and a digital base map created for them by a private engineering company. Figure 4 shows a sample of this database. As with Brookline, Springfield has an active street tree management infrastructure and was therefore interested in this pilot study.

Copies of the aerial photographs were obtained and assessed for the ability to accurately identify tree locations. As was found previously, even this larger scale was not sufficient to positively locate trees because of the shadow effect. This was especially difficult in downtown Springfield where there are many very tall buildings. Again it was concluded that these aerial photographs were not suitable for this project.

Since a group of volunteers was again being assembled and trained in tree mapping and attribute collection, it was decided to test different tree mapping techniques in Springfield. How well could the tree information be transferred to the existing base map, one that had street edges but not building footprints, sidewalks or other helpful references? Working again with University of Massachusetts Urban Foresters and officials from the City of Springfield, activities were coordinated and the project was successfully implemented.

Procedures were very similar to those used in Brookline. Volunteers recorded tree locations on 1"= 50' (1:600) scale parcel maps that showed street edges, street names, building footprints and addresses (shown in Figure 5), and entered tree attributes into the computers. In Springfield, however, it was more difficult to transfer tree locations to base map without the reference that the building footprints and sidewalks provided. However, there were only a few areas that were especially challenging and most of the work went very well. Figure 6 displays completed tree mapping integrated with the digital database.

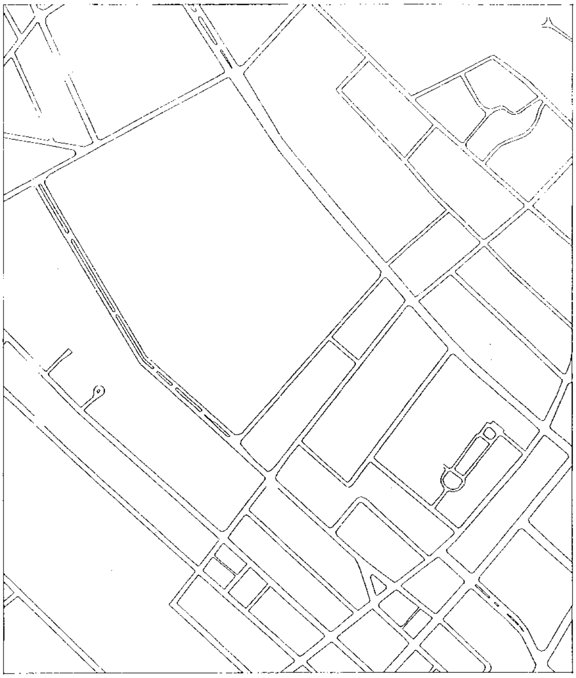

Figure 4. Sample area of the Springfield digital database.

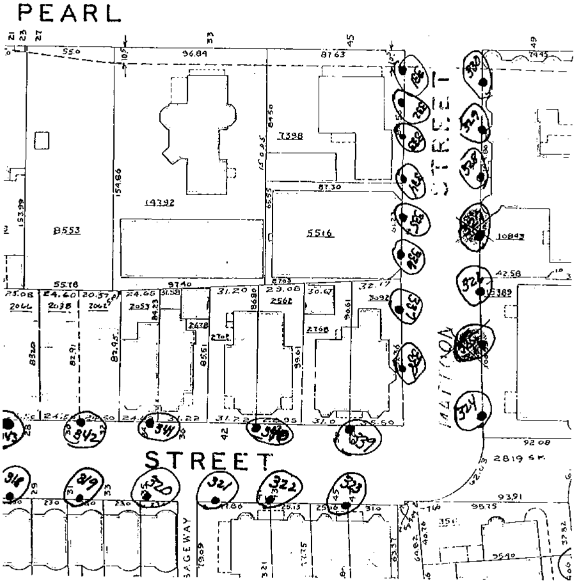

Figure 5. Sample field map for Springfield study.

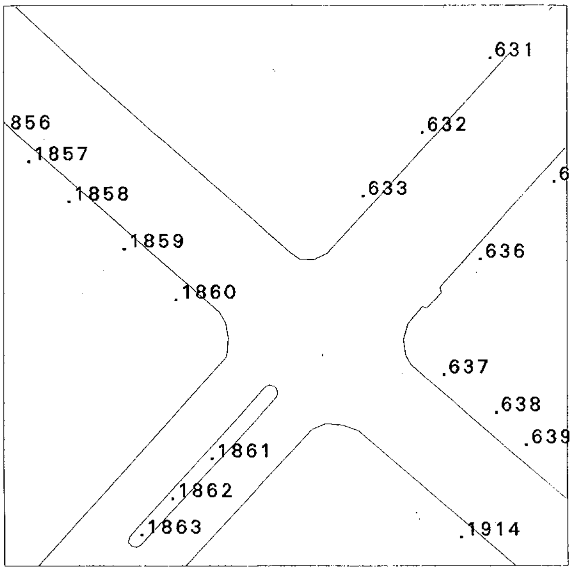

Figure 6. Digitized tree locations integrated with digital base map for Springfield.

Assessment

It was clear from both of these case studies that the final approach worked. Ideally, a detailed analog or digital base map used in conjunction with maps showing tree locations collected in the field and a computer database can be put together to create a tree inventory system. Brookline had very good data sources and as a result, the project was a success. Springfield had good data sources, not as comprehensive as Brookline, but certainly adequate to do the project. The importance of building footprints for street tree mapping cannot be overemphasized. Brookline had them on both the parcel maps and the base map while Springfield only had them on their parcel maps making transfer more difficult.

Base map scale worked best in the 1:1,500 to 1:3,000 range. In Brookline, where there was a digital base map, the scale was adjusted in different areas. In the urban core areas, base maps at 1:1,500 were created. In the more suburban areas, 1:3,000 scale base maps worked better. The same held true in Springfield. Both base maps were adequately geo-referenced, so there was not any reason to question their accuracy.

Mapping trees from aerial photography was less successful than expected. In many situations, trees could be identified with great accuracy. However, this was limited to streets that did not have large buildings that created shadows. It was also found that streets that ran north and south were confusing because even if the tree crowns were not touching, often their shadows were touching and this made it difficult to know how many trees were being viewed and where their bases were located. This was a problem along other streets as well. The tree could be seen but it was unclear where the base was located. Also, with the photography used, smaller trees were consistently missed. It was also difficult to distinguish small trees from large shrubs and street trees from non-street trees, something that is not a problem in the field.

Despite a lot of the positive qualities inherent in GPS and surveying techniques, it seemed that the accuracy may not be sufficient with a general grade GPS receiver even though the total time to gather the data was considerably less. In Brookline where 10,791 trees were mapped, it would have taken a very conservative 719 person-hours to gather GPS data without assurances that readings could be obtained for all trees in the "urban canyon" or that the satellite constellation would be favorable for signal tracking. In Springfield where 1,113 trees were mapped, it would have taken 74 person-hours to gather GPS data in an area of much taller buildings so the success rate would have been even lower. No estimates can be made on the time to gather this information with a total station-surveying approach.

It is interesting to compare these times with the actual time spent by the field volunteers collecting location and attribute data. In Brookline, 1,872 person-hours were logged gathering tree attributes (not including training time for volunteers) while in Springfield, 536 person-hours were logged. These times make GPS mapping look very attractive, especially considering that the transfer and digitizing steps would not be necessary with GPS, only post processing, database integration, and data conversion to conform to base map units. Using GPS receivers in these two communities would have required the purchase or rental of many units plus training for their use (in addition to the tree identification, attributing and mapping training already done). Also, the accuracy issue continues to be questionable - would it take a surveyor's grade GPS unit to locate these trees in their proper relative location? If so, these units would have been prohibitively expensive for this type of project.

Both sets of parcel maps in both communities worked well. The combination of streets, street names, building footprints and addresses was critical for mapping tree locations. When this information was transferred to the base map, there were only a handful of questions about the tree locations, generally because of illegible handwriting, messiness or failure to make a large enough dot indicating tree location by the field technicians. It seemed that they were almost always able to decide on a tree location using these maps.

The program that was used for this project was written in BASIC and was used on a DOS based computer. It was easily copied to any IBM compatible computer. It was created in two parts, the program itself and a batch file that executed the program. It took a number of iterations to work out the bugs by anticipating as many operator mistakes as possible.

Several problems were discovered, mostly attributable to user error in the field or unfamiliarity with general computer operating technique. These problems, however, were minor compared to the large number of entries that were successful. After the volunteers gained a moderate familiarity with this program, it worked very well.

Once maps were completed with tree locations and unique identification numbers that matched the number used in the computer database, this information was transferred to the base map and digitized with GIS software. Transfer and digitizing went very smoothly as noted previously.

The biggest problem encountered was with duplicate or missing tree numbers either on the field maps or in the database. Each team of volunteers was given a unique geographic area and a unique range of tree numbers to avoid duplication. This worked well in almost every instance but there were occasionally illogical, duplicate or missing numbers that indicated an inconsistency. When this happened, the field coordinator was consulted to get their input on how to resolve the matter without having to revisit the site. Ultimately, all questions were answered.

Once the database was corrected, the spatial tree location data were joined with the database using the unique tree number to properly merge them together. This worked flawlessly and all the attributes were then associated with the tree location. An inquiry could then be made using the GIS to perform a spatial query or analysis based on any of the tree attributes. For example, all white oaks with a dbh larger than 15" that need pruning could easily be identified. If parcel ownership were available in this example, it would be simple to locate the name of the person on whose property this tree grew.

Conclusions

An effective street tree inventory can be implemented with good parcel maps, good base maps, a team of trained field people, a computer program to record attribute data, hand held or portable computers, a transfer scope, and GIS software. Two case studies were completed using the techniques described above.

This research demonstrated that aerial photographs were less effective then expected for creating a street tree inventory. Large scale photography may be necessary to do a street tree inventory, perhaps photos as large as 1:2,400 (1"=200') scale. Without large scale photos, it would be very difficult to implement an urban tree mapping project from aerial photographs because of the problems of tree and building shadows and other difficulties in properly locating individual street trees.

GPS may be an excellent technology to use for these purposes, but in a heavily urbanized community it would be difficult to receive sufficient satellite signals to accurately map all of the streetside trees. A surveyor's grade unit may be necessary to insure accurate tree placement. This is an area that should be explored in future research.

Analog orthophotoquads made from 1:30,000 scale photographs and produced at 1:5,000 scale were not very useful for checking tree locations in the field. Even though there is a lot of information on these maps, poor image quality and lack of sufficient cultural data made it difficult to pinpoint tree and human locations. Large scale orthophotoquads with more complete cartographic information may solve these problems.

What can be accomplished in towns that lack good base maps, good parcel maps or large scale aerial photography? Without an acceptable base map, it would be necessary to either have one created by a reputable photogrammetry or engineering company, or photographically enlarge a good, existing map (such as a USGS topographic map) so that it was at a large scale. A good parcel map is not necessary if the base maps can be taken into the field and contains adequate map features for accurate tree location mapping. The final digital product in Brookline contains all the elements to do this while the final digital product in Springfield without building footprints was not adequate for field use. However, when additional digital data layers are created, they can be integrated with the tree database for greater utility. Once all of these steps have been performed and integrated, the groundwork has been laid to implement a street tree management system.

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Project Manager
Resource Mapping - Land Information Systems
Department of Forestry and Wildlife Management
301 Holdsworth Hall
University of Massachusetts
Amherst, MA 01003

Résumé. La disposition d'un inventaire informatisé des arbres de rues utilisant un système d'information géographique (SIG) peut grandement améliorer la gestion des arbres municipaux. Plusieurs techniques différentes ont été explorées dans le but de rendre plus efficace et précis la localisation des arbres sur les plans incluant la photointerprétation aérienne, les sytèmes de positionnement global, les techniques d'inventaires et la localisation des arbres à partir des plans de base existants. Les données sur les caractéristiques des arbres ont été recueillies sur le terrain en employant un ordinateur portatif préprogrammé afin de rendre ces données compatibles avec un système d'information géographique. Les données de localisation spatiale des arbres ont été jointes à celles des caractéristiques de ces derniers afin de créer une grande base de données pleinement fonctionnelle pour des fins de gestion des arbres de rues.

Zusammenfassung. Die Entwicklung einer Bestandaufnahme von Straßenbäumen unter Anwendung des Stofware-angebots Geographisches Informations-system (GIS) kann die Arbeit kommunaler Grünflächenämter entscheidend verbessern. Um effiziente und akkurate Standortpläne für Bäume zu erstellen, wurden verschiedene Techniken einschließlich Luftbildinterpretation, Sateliten-aufnahmen und Übertragung von Bestandsaufnahmen auf vorhandenen Pläne bezüglich ihrer Eignung erforscht. Mittels eines tragbaren, vorprogrammierten GIS-kompatiblen Computers wurden detailierte Baumbeschreibungen vor Ort erfasst. Die räumlichen Baumstandortdaten wurden mit den Daten zur Baumcharakteristik verbunden un ergaben so eine voll funktionsfähige Datenbank für das Management von Straßenbäumen.