A GEOGRAPHICALLY REFERENCED TREE INVENTORY SYSTEM FOR MICROCOMPUTERS

by Robert C. Maggio

Abstract. A geographically referenced inventory was installed in the town of Highland Park, Texas. Field data were collected using aerial photographs to locate each tree in the field and tree characteristic data were recorded for all trees in the parks as well as all street trees. The locational data were digitized into the computer and characteristic data entered into a database manager. The database can be queried to locate a single tree, all trees on a block, a series of blocks, a park, or the entire town. All queries can result in a plot to the computer monitor or plotter. Characteristic data may be output to the monitor or printer. Business graphics output is also available with the database manager. Updates to the inventory include deletions, additions, and changes in characteristic data which can keep the inventory current.

The urban forest, like the industrial forests, requires planning, maintenance, protection, and regeneration. In order to establish, maintain, and perpetuate this resource, urban foresters must have up-to-date information concerning the resource that they are charged with managing. Inventories are performed on industrial forests on a regular basis to provide foresters the necessary information to manage the forest resource. Urban tree inventories can provide managers the necessary information to allow them to plan and perpetuate the urban forest (3).

Computer-based tree inventories have been developed for entire cities and for individual, highly used city parks (6, 2). A tree inventory for the City of Ft. Worth, Texas utilized aerial photos to locate tree positions and ground inventory procedures to determine characteristic data—dbh, species, vigor (4). This inventory was to be based on a mainframe computer. McPherson (1984) used a grid cell approach to locate each tree in a portion of a city park and developed an inventory system for a microcomputer that would allow search and retrieval by location and characteristics. Other inventory systems have relied solely on street address for tree location, and both tree characteristic and location data have been stored in a database management system such as dBase II or III (1). Entries to the system are limited to street address or tree characteristics. Tree inventories have typically not been able to map geographically the results of a search of the database to provide a visual representation of the location of the trees that resulted from the search.

Objective. This article describes the creation of a microcomputer-based urban tree inventory for the Town of Highland Park, a municipality located within the city of Dallas, Texas. The town covers 288 city blocks, 46 miles of streets, and contains 51 acres in 12 parks. The objective of this project was to inventory the location and characteristics (e.g., data concerning species, dbh, condition, etc.) of every tree on city rights-of-way in the Town of Highland Park. This included trees between the sidewalk and curb on streets, trees in all boulevards and traffic circles, and trees in all parks.

This tree inventory is a microcomputer-based system with graphic output of database searches to either a computer monitor or hardcopy plotter. The inventory system is operational on an IBM-PC XT with graphics display. Peripheral equipment interfaced with the IBM are a Hitachi 11" X 11" digitizer for tree location data entry, a pen plotter for hardcopy plots, and a dot matrix printer for tabular listings.

Planning. To facilitate planning and location of each tree, color infrared aerial photographs of the town were acquired at a photo scale of 1"=200'. This scale was chosen so each tree crown could be seen and numbered on an overlay to the photo. Utilizing these photographs and maps of the town, it was decided to perform the inventory on a block-by-block basis.

Field data collection. All data were collected by three field personnel, with each assigned a series of blocks to inventory. Each was equipped with a range finder for determining crown diameters, a Biltmore stick for dbh (diameter breast high) estimation, tally sheets, aerial photos and frosted acetate overlay material.

Acetate overlays were placed over each photo and a dot was placed on each tree visited in the field. A unique tree number was placed by the dot on the overlay and recorded on the tally sheet (Figure 1) along with the tree characteristic data shown in Table 1.

Data Entry

Characteristic Data. All characteristic data recorded on the tally sheets were keypunched into the IBM-PC. A data entry program that would allow the operator to duplicate data similar from one tree to another was written to speed entry of repetitive data such as date, street address, and condition when these data were the same for several trees.

Locational Data. All tree locational data (the dot placed on the photo overlay and its corresponding tree number) were transferred from the aerial photo overlay to an overlay of a basemap of the entire town. The overlay to the basemap had each block outline delineated and each tree on each block was represented by a dot which depicted its exact location on the block.

The basemap overlay with all trees located on it was placed on a digitizer interfaced to the IBM-PC. The perimeter of each block was digitized and given a block number. The digitized data were displayed to the monitor on the IBM and simultaneously stored on disk. The beginning and ending sequential number assigned to each tree on the block was then entered. Next, each tree's location was digitized one at a time to create a data record that was made up of block number, tree number, and tree location.

Analysis of Data Collection

Table 2 shows a breakdown by task for the field data collection and data entry to the tree inventory software. Field data collection required the most amount of time (216 hours) and was by far the most costly activity. Keypunching and digitizing activities were tedious and the activity which had the highest potential for error. Data editing involved proofing the data base for completeness and detection of errors generated by data entry.

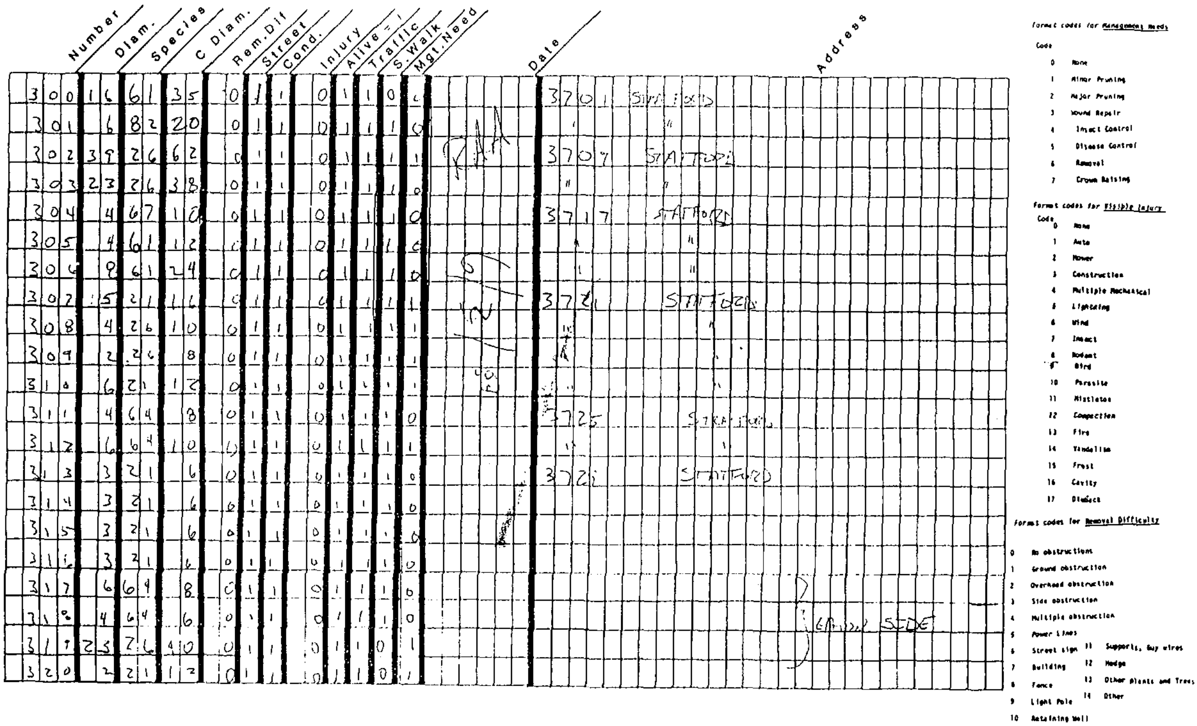

Figure 1. Coded field tally sheet.

Data Consolidation

At this point, there were two separate data files. One file contained the characteristic data collected in the field, while the other contained the digitized tree locations. The one item both files had in common was the tree number. This number was used to consolidate both files so that each tree had a data record with both characteristic and spatial location data in it. Once the master data file was generated, each tree was renumbered using the block number as a prefix and the trees on each block were numbered sequentially (ex: 42:36, tree 36 on block 42). This technique allows for easy addition or deletion of trees from the block without having to renumber the entire database.

Within the database, there were three sub-databases: street trees, park trees, and parkway trees. These three sub-databases exist because the three categories of trees are managed differently. Street trees are typically cared for by the residents of the home in front of which the trees are growing. These trees usually require less maintenance by the town's forestry department. Those trees on the parkways are the responsibility of the forestry department and, since they are highly visible, require frequent attention. Park trees are managed for aesthetics and for shade production, so these trees require yet another type of management.

Table 1. The field data collected for each tree.

Tree number	Sequential number noted on tally sheet and corresponding photo overlay
Species	Coded species number
Crown diameter	Recorded to nearest whole foot with range finder
Removal difficulty	A coded number from a list of 15 potential obstructions
Street, park, or parkway	Street trees are trees between the sidewalk and curb. Park trees are trees in designated park areas. Parkway trees are those lining boulevards and in traffic circles.
Condition	One of four well-defined categories: good, fair, poor, dead
Injury	One of a list of eighteen possible injuries
Hazard	Sidewalk hazard—roots have caused sidewalk to be disjointed and caused a vertical displacement of greater than 2". Street hazard—roots have caused curb to be broken and to protrude into street.
Management need	One of 7 categories describing the management needs of the tree
Date	Date the field data were collected
Address	The street address of nearest numbered residence or business. In case of park trees, park name was used. In parkway trees, the name of the parkway was used.
Location	Each tree was numbered and its number recorded on the tally sheet. Each tree was also located on the aerial photograph, a dot placed on it and the tree number written beside it.

Database Search and Retrieval

Many urban tree inventories allow the user to search and retrieve data from the database by keying on the variables recorded for each tree (characteristic data). In such inventories, queries are not possible by tree location other than to key on a street address. Grid systems have been used (5) to locate trees in a park. This allows the user to locate trees by the grid cell it is in. With such a system, a tree is located only by the grid cell it is in. Any grid cell may contain several trees and

Table 2. Time requirements (by category) for database generation.

Task	**Total time*	*Time/tree*
Field data collection	216.0 hr.	1.55 min.
Keypunch characteristic data	44.5 hr.	.32 min.
Digitize tree location	30.5 hr.	.22 min.
Edit data	50.0 hr.	.36 min.
		**2.45 min./tree

*The times reported in Table 1 reflect actual time required to perform the steps described. Field data collection time does not include travel time to and from the city.

**Per tree mean based on a total tree count of 8361.

when mapped output is requested for any tree in the cell, the entire cell must be mapped. When there are several trees in a cell, their location and distribution within the cell is not known. If a grid cell system is used for street trees, tree location is limited to the cell it is in. If two trees are side by side, in the same cell, but are planted in front of 2 separate houses, mapped output for either tree would cause the entire cell to be plotted.

The inventory technique used in this project allows the search and retrieval of data utilizing either the characteristic or locational data, or a combination of both. The user first chooses the sub-database (street, park, parkway) to use and then defines the area of the town to be searched. This is accomplished in a number of ways: 1) defining the block numbers to be included in the search, 2) the park to be searched, 3) the streets by name and block address (e.g., 3600-4500 block of Mockingbird, or 4) any combination of items 1-3 to define the search area. Once the search area is defined, those characteristics and ranges of each characteristic are defined. An example of a search is as follows:

Street trees
Blocks: 168-200, 144, 16-23
Species: 64, 60, 61
dbh: 1-12
Condition: Poor
Visible injury: 11

This would search blocks 168-200, 144, and 16-23 in the street tree sub-database for live oaks, red oaks, and Shumard oaks that have a dbh between 1-12" that are in poor condition and that have mistletoe growing in it. The results of this search would yield a small data set removed from the database that can be plotted to the IBM-PC monitor or the plotter. This plot will show the perimeter outline of each block with only those trees that fulfilled the search constraints (Figure 2). Each tenth tree will be numbered on the plots. This number will correspond to a listing of the characteristics of each tree that appears on the plot. With this type of search, retrieval and portrayal, the user can inspect not only the list of those trees that were included in the search, but he can also view the distribution of those trees on the block to see if they are grouped in one portion of an area or evenly distributed throughout. This type of search and portrayal would be of great use when planning the location of new trees on streets that already have some trees but need more.

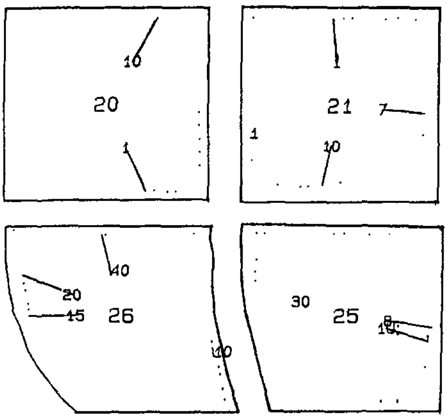

Figure 2. Graphics plot of tree inventory database search.

The results of a database search can also generate a data file which can then be utilized by a database manager to provide business graphics output. Figure 3 shows the dbh distribution of American elm for all street trees.

Updating

Any tree inventory is only as good as the data in the database. With the passage of time, tree inventory data becomes outdated and provisions must be made to keep the database updated. There are several ways a database can be kept up-to-date. As time, manpower, and resources become available, a re-inventory to update

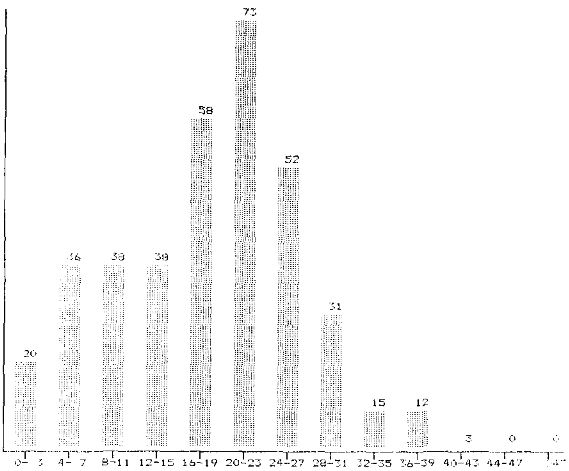

Figure 3. Frequency distribution by dbh class for Species 26 (American Elm).

characteristic data can be done. This would be done only if absolutely necessary. An alternative to this would be to have town tree maintenance crews and private tree maintenance crews report all work done on existing trees. In the present study, a Service Request Form (SRF) is issued each time a home owner requests any work be done on trees in front of a home. Information from the SRF (primarily street address) will be used to search the database for those trees growing in front of a numbered house address (ex. 3702 St. Johns). The characteristics of those trees selected from the database will be listed to the printer along with all other trees on the 3700 block of St. Johns. A map of this block will be generated to the plotter and the trees in front of 3702 St. Johns will be labeled with an asterisk while the remaining trees will be denoted with dots. Every tenth tree will be numbered on the plot and this number will correspond to the characteristics of those trees listed for the block. Once a field crew has taken these forms with them to the field and performed the necessary work, the SRF is returned to the office with the description of the work performed and changes to any of the characteristics that are necessary to update those trees serviced. Tree removal can also be handled with the SRF and the tree removed from the database.

As tree planting activities are undertaken, those trees planted must be entered into the database. When tree planting is planned, plots and characteristic lists are obtained from the database for those areas to be planted. Tally sheets, similar to those used for the initial inventory, will be filled out for each tree to record the characteristic data. The position of each new tree will be located on an aerial photo or a computer-generated map of the block. Each new tree will be given a tree number with the block number as the prefix and a tree number equal to the highest numbered existing tree on the block plus 1. For example, block 162 has 32 trees on it, any new trees would begin with 162:33.

Once these data have been recorded in the field, the characteristic data are then entered into the database. Utilizing the program for updating, the characteristic data are keypunched and the location of the tree is digitized using the aerial photo or map on which it was located in the field.

Information concerning the time, manpower, and equipment required to maintain the urban trees is recorded on the SRF and is recorded in the database. Trends concerning the time required to perform service, equipment needed, costs, and those trees requiring the most maintenance can be developed over time.

Conclusions

Urban tree inventories exist in many forms, but the techniques used in this project allow for storage, retrieval, and portrayal of both characteristic and locational data. This database can be maintained with minimum effort if the user makes every effort to utilize feedback of information from field crews. This system provides the urban forester the ability to search the database for a single tree, a block, an entire street that spans many blocks, a designated portion of a city, or the entire city. Searches can provide exact location and distribution of trees by any characteristics and any range of any characteristic. Results of any search can be plotted to a monitor or plotter. This technology will give the urban forester the best possible planning and maintenance tool needed to manage the urban forest.

Acknowledgments. Funding for this project was provided by Trees For The Town, Inc., Town of Highland Park, Texas.

Literature Cited

1. Barker, P. A. 1983. *Microcomputer databases for data management in urban forestry.* J. Arboric. 9(11):298-300.
2. Giedraitis, J. P., and J. J. Kielbaso. 1982. Municipal tree management. Urban Data Service Reports. Vol. 14, No. 1. Washington, D.C.: International City Management Association.
3. Grey, Gene W. and Frederick J. Deneke. 1985. Urban Forestry. Wiley & Sons, Inc. N.Y. 277 pp.
4. Massey, Joseph G., W. K. Murphey, and R. S. Dewers. 1979. *The economics of urban tree inventory systems: Fort Worth, a case study.* J. Arboric. 5(10):233-235.
5. McPherson, E. G. 1984. A Utah Park Tree Inventory System and Case Study. Technical report available from the Utah Division of State Lands and Forestry. 355 West North Temple, 3 Triad Center, Suite 400, Salt Lake City, UT 84180-1204.
6. Weinstein, G. 1983. *The Central Park tree inventory: a management model.* J. Arboric. 9(10):259-262.

Department of Forest Science
Texas A&M University
College Station, TX 77840-2135