REMOTE SENSING SURVEY OF PECAN TREES IN FIVE TEXAS CITIES

by L. C. Rodgers and M. K. Harris

Abstract. Canopy coverage of the total tree populations and pecan tree populations in five Texas urban areas were estimated and recorded based on an existing method of survey. This method utilized color infrared aerial photography in conjunction with the Universal Transverse Mercator grid system to inventory the trees and create a permanent data file for each urban area.

Several modifications were made to increase the compatibility of the existing survey method to urban areas and to expand the amount of information recorded for each area. Analysis of the data collected was based on computer software programs, and the output was in tabular and graphical formats. Uses of these types of data files include landscape and city planning, surveys, and monitoring vegetation for disease or insect pest outbreaks.

The development of a comprehensive tree maintenance program in urban areas is perhaps best accomplished by identifying each tree species; determining their abundance and condition; and developing a plan to address problems the present tree population is likely to face, along with ways to minimize these problems without introducing others through future landscape planning. The pecan tree, *Carya illinoensis,* is a native North American tree that is found in many urban and rural areas of Texas with approximately 23 million pecan trees located in 340,081 hectares across the state (McWhorter et al. 1980). The abundant population of the pecan tree makes it an ideal species to demonstrate the initial step of creating an effective tree maintenance program. This paper outlines that step through a procedure to identify and categorize pecan trees in relation to other tree species in urban environments in the southwest.

One solution to the problem of collecting vegetation data is the use of remote sensing techniques. Color infrared (CIR) aerial photography has become a useful survey tool that provides a permanent record from which future changes in the vegetation can be measured (Heller 1978), and it can be used as the major source of information to create data bases describing various classes of vegetation in an area (Gammon and Carter 1979). Surveys using this type of photography are possible because the CIR film enhances the visibility of vegetation on the resulting photographs due to its sensitivity to the infrared portion of reflected light. These infrared reflections are recorded as various shades of red depending on the amount of radiation reflected by the plant. Conditions that affect the amount of radiation reflected include the amount of water in the soil, the composition of the plant, and the presence of disease (Taranik 1972).

Several studies have documented the successful use of CIR to detect damaged vegetation. Murtha (1978) discusses the change of the spectral reflection of the leaves based on morphological and physiological damaging agents such as insects and disease. Norman and Fritz (1965) were able to detect disease and decline in a citrus grove, and populations of brown soft scale were identified through the presence of sooty mold which affected the reflection of the leaves (Hart and Myers 1968). Therefore, this type of photography is of considerable value to entomologists and its possible uses may be summarized as: the detection of the pest and its presence throughout the year, the ecology of the host plant, and the evaluation and assessment of control measures (Hart et al. 1971).

The presence of disease and insect pests in pecan tree orchards have also been identified through the use of aerial photography with infrared film in a study by Payne et al. (1972). Harris et al. (1976) documented the defoliation and regrowth of pecan trees following a walnut caterpillar infestation, and demonstrated the effectiveness of aerial infrared photography as a survey tool. From the latter study, a system to monitor pecan trees in Texas was developed which created a permanent data base for future monitoring of native pecan tree populations located along three major rivers in Texas (Maggio 1980, Maggio et al. 1982). This classification system involved the use of computerized information collected from aerial photographs to provide an economical method for cataloging, sorting and analyzing the data. Although this study did include pecan trees in urban settings along rivers, it did not exploit the survey to its fullest potential in those areas.

In the present study, the total percent of the pecan tree canopy coverage versus the total canopy coverage of all trees in five Texas cities were cataloged and analyzed into geographic bases (Rodgers 1982), based on theories and practices outlined by Maggio (1980). These data bases were developed to aid in the maintenance and perpetuation of urban vegetation such as the pecan tree.

Materials and Methods

The selection of urban areas in this study was limited to cities covered by CIR aerial photographs taken during missions flown by the USDA Citrus Insects Laboratory in Weslaco, Texas for the native pecan tree survey. Cities selected for interpretation in the present study were Ozona, Iraan, Richmond and portions of Austin and Pecos, Texas (Fig. 1).

A grid system was used to index each hectare

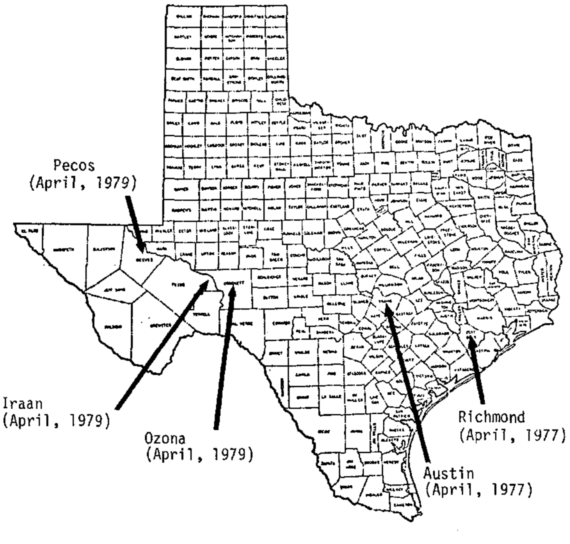

Figure 1. Location of the five cities included in the present study. *The dates indicate the month and year that* the areas were photographed.

photointerpreted. This system was developed by Maggio (1980) and Maggio et al. (1982), and was based on the Universal Transverse Mercator (UTM) grid. The UTM coordinates are located along the margins of 7 ½ ° U.S. Geological Survey (USGS) quadrangle maps. When these coordinates are connected, each resulting square kilometer is assigned a permanent reference number that is made up of the UTM zone number and the X and Y coordinates. The grid system was then superimposed over the photographs on acetate overlays that were made by enlarging the USGS maps so the scale of the UTM lines and the scale of the photographs corresponded.

The square kilometer locations on the photographs were overlayed with breakdown grids drawn on clear acetate. Each breakdown grid represented a square kilometer subdivided into one hundred parts, each part representing one hectare. Grids available for the existing project were for use with photographs at a scale of 1:10,000 (the natural scale is the camera focal length over the altitude at which the photographs were taken; see Avery 1977). Although film for 2 of the 5 areas of this study were at a scale of 1:10,000, the remaining 3 cities were at a scale of 1:5,000, for which there were no available breakdown grids. Therefore, a computer graphics program was written to generate accurate and economical grids. These grids were then traced on the clear acetate. Further modifications of this program resulted in the generation of the quarter hectare grid. This modification partitioned the square kilometer into 400 quarter hectare cells and expanded the numbering system so that each quarter hectare was designated by a letter.

Once the breakdown grid was in place, each hectare or quarter hectare was evaluated on the basis of the trees within its boundaries. Images of pecan trees on CIR photographs taken in April have only a few leaves or a small percentage of bud break, in contrast to most other hardwood trees in full foliage that appear as various shades of red. The images of pecan trees on photographs at a scale of 1:5,000 have a gray shadow; however, photographs of pecan trees at a scale of 1:10,000 have a pink coloration. Because of this slight variation of images, initial readings of film at the 1:5,000 scale contained misinterpretations of trees with similar appearances of pecan trees at a scale of 1:10,000.

Photointerpretation errors and the accuracy of the data were verified during a ground truth survey conducted in Ozona. Twenty quarter hectare areas were randomly chosen for field checks with 10 sites photointerpreted as containing pecan trees and 10 areas interpreted as being without pecan trees. The field checks were done by taking the film transparencies to the field and visually comparing each site to the photograph.

Data from each hectare or quarter hectare site were recorded in the form of statements on precoded computer data sheets. Each statement was made up of 27 numbers that were representative of the cell location and the vegetation information. These statements could be further modified to represent other information concerning urban areas such as the building coverage.

The first part of the data statement identified the UTM coordinates and breakdown grid number or letter. Following this was the land classification code. The majority of the information used only three classifications: urban areas, river areas, and out of town areas (only used during the interpretation of Ozona.) Additional codes may be used which designate various areas such as residential, commercial or industrial. The tree population data were recorded by both the percentage of each hectare covered by all species of trees and by the percentage of pecan trees located in that hectare. The last portion of the data statement contained the frame number and additional information about the vegetation, if desired.

The data statements were transferred to the university computer (Amdahl 470/V6/V8) and stored on individual files. These stored files were then processed through 3 editing programs (Maggio 1980). The purpose of these editing programs was to locate any errors in the data files so that they could be corrected before the data were presented in a tabular or schematic format.

Schematic presentations of the data were done by using a statistical program. This program determined the frequency of cells on the basis of the percentages recorded in the data statement, and the output was in two parts, tabular and a histogram. Another schematic presentation was also available which reproduced the data based on each hectare cell and formed a graphical map of the area. Different tonal patterns were assigned to each percentile range to distinguish the density of arborial growth. The UTM permanent numbers and breakdown grid designations were listed around the perimeter of the diagram so that each cell could be identified and referenced back to the photographs or data statement (Maggio 1980).

A computer program was written that determined the actual canopy coverage of a cell, that is, the amount of land covered by the canopy of the trees or pecan trees from an aerial view. This program converted the percentage of trees and the percentage of pecan trees in each statement to actual hectares covered. It then calculated the average hectare canopy coverage for all tree species or pecan trees only. The average number of pecan trees based on the number of cells containing pecan trees was done manually using the sum of total pecan tree coverage produced by this program.

Results and Discussion

The city of Ozona was the first urban area to be interpreted, and its moderate size and large pecan tree population made it an ideal choice for testing the practiality of using a quarter hectare breakdown grid rather than a hectare breakdown grid. Over half of the hectares containing trees included at least some pecan tree canopy (227 hectares, out of a total of 318 hectares containing trees, had some pecan tree canopy coverage). Figure 2 presents the frequency of hectares for both the total tree population and the pecan tree population in each percentile range. For both types of information, the 1-10 percentile range had the greatest number of hectares followed sequentially by the other ranges.

The quarter hectare breakdown grid presented the tree population data based on a smaller area. This made is possible to classify the urban areas in each quarter hectare (Table 1). Widespread use of trees, especially pecan trees, in the residential area was suggested by comparing these figures with the number of trees occurring in other categories. Of the 882 quarter hectares containing some tree canopy coverage, 660 were located in the residential area, and of the 480 quarter hectares containing pecan trees, 401

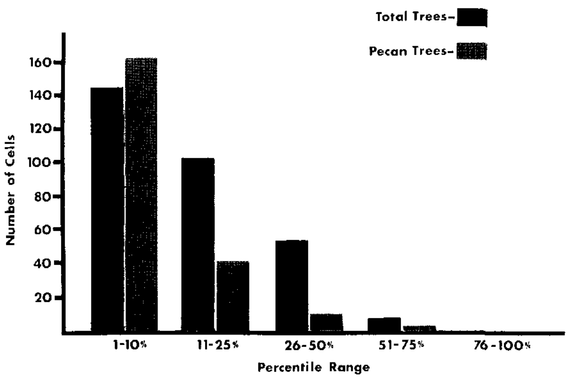

Figure 2. A frequency distribution of the total tree canopy coverage and the pecan tree canopy coverage by hectares in Ozona, Texas. The distribution is given by the number of cells in each percentile range.

were also found in the residential areas.

Since Ozona was the first city interpreted, some misclassifications of trees did occur and were discovered during the ground truth survey. Trees most commonly misclassified as pecan trees were: elms (*Ulmus* sp.), mesquite (*Prosopis* sp.), and the tree of heaven (*Ailanthus* sp.). Once the differences between these trees and the pecan tree were recognized, the remaining four cities in this study were interpreted.

Subsequent analysis and comparison of the tree population data for all 5 cities included in this study indicated a decrease in the density of the tree population as the survey progressed from east to west across the state of Texas. These comparisons were made from the output of the program that produced the actual area of land covered by the tree crown canopy, (Table 2). The city with the largest area covered by tree canopy in this study was Richmond with 160 hectares; followed by Austin with 139; Ozona, 53; Pecos, 20; and Iraan with 11 hectares. The city with the largest pecan tree canopy coverage was Ozona which had 23 hectares covered. This was followed by Richmond which had 20 hectares covered by pecan tree canopy, Austin with 11, Iraan with .62, and Pecos with .07. Richmond had 14 hectares which exclusively contained pecan trees, Ozona had 8, there were 2 in Austin, and both Pecos and Iraan has no hectares with only pecan trees.

The information in Table 2 is not representative for the cities of Pecos and Austin since only four square kilometers were interpreted; therefore, in order to better compare these data, the average number of trees and pecan trees per hectare were calculated (Table 2). This changed the city with the largest tree population to Austin which had an average of 39% total tree canopy per hectare. This was followed by Richmond with 34% trees per hectare, Ozona with 17%, Iraan with 8%, and Pecos with 7% total tree canopy coverage.

Although two types of averages were calculated and presented for the pecan tree canopy per hectare, the average based on the total number of cells containing pecan trees was used. Thus, the city with the largest average pecan tree canopy coverage per hectare was Richmond with 13%, Ozona had 10%, Austin with 9%, Iraan had 1.9% and Pecos with 1.7% pecan tree canopy coverage per hectare.

After comparing the 2 sizes of breakdown grids used to collect the tree canopy information, the hectare breakdown grid was determined to be the appropriate size for this study. The additional time

Table 1. The frequency of quarter hectare cells by land classification in Ozona, Texas.

Land classification	*Total cells*	*Cells with trees*	*Cells with pecans*
Out-of-town	735	7	0
Residential	819	660	401
Industrial	7	2	1
Commercial	188	68	37
Community Facilities	159	57	26
Undeveloped Areas	222	40	7
Developed Recreation Areas	75	48	8
Freeway	75	0	0

Table 2. Summary and Comparison of the tree stand data collected from aerial CIR photograph of all five Texas cities.

City	Total hectares photointer-preted	Total hectares covered by trees	Number of cells containing trees	Total hectares covered by pecans	Number of cells containing pecans	Average percent trees per hectare	Average percent pecan trees per hectare (based on total trees)	Average percent pecan trees per hectare (based on total trees)
Ozona	431	52.69	318	22.77	227	16.57	7.16	10.03
Iraan	166	10.89	128	0.62	32	8.51	0.48	1.93
Richmond	508	160.22	475	20.52	156	33.73	4.32	13.15
Austin	400	138.72	352	11.09	121	39.41	3.15	9.16
Pecos	365	19.72	292	0.07	41	6.75	0.24	1.73

required to interpret the quarter hectare breakdown grid and analyze the data was not justified by the information collected in this study. Although each hectare cell contained a larger area to interpret, the same information was available, and additional categories could be successfully included. Detailed information, such as land use classification of each cell, was possible with the one hectare cell, but it was not as accurate as the quarter hectare data because of the greater number of combinations encountered in the larger area.

Details of the urban areas were not as visible on photographs at a scale of 1:10,000 as they were on those at 1:5,000 scale. However, photographs at a scale of 1:10,000 required less movement of the breakdown grid from one photograph to another to record the data for the square kilometer. All of the information required for this survey was visible on film with a scale of 1:10,000.

Conclusion

This study successfully utilized methods developed by Maggio (1980) to create data bases for pecan trees in five Texas cities. Information included in the resulting data files varied, but the distribution and abundance of all trees, specifically pecan trees, were emphasized throughout the survey. This information was collected from CIR aerial photographs and stored on computer files for future references.

Data collected in this survey for the pecan tree population was compared to the total tree canopy coverage in the same urban area. The accuracy of this information was verified by a ground truth survey. That survey not only located errors, but it also increased the confidence and accuracy of the interpreter.

Because of the large number of statements in each data file, the data were reproduced by the computer in tabular and diagrammatic formats. In addition, the computer provided a means by which this information is now readily accessible for future reference and comparisons to monitor the changing urban environment. Since this type of survey provides a convenient method to obtain a permanent record of an area with a minimum of man-hours spent in the field, it is less expensive than ground surveys for obtaining information (Harris et al. 1976).

The use of the computer also made it possible to compare the modification of the hectare breakdown grid to a quarter hectare breakdown grid. Although the latter provided additional information, the details desired in this survey could be accurately obtained with the hectare breakdown grid. Information collected in this study for the percent canopy coverage by total trees and pecan trees using both sizes of grids was basically the same; however, some discrepancies did occur. These were attributed to the placement of the grid and human error.

Once a data base is created following the procedures outlined in this study, a valuable tool is ready for use by many professionals in the urban community. This group includes city planners, home owners, real estate agents and industrialists who could use general information about the community and its growth. Vegetation assessment is a valuable aspect of this type of survey. Such an assessment not only provides horticulturalists and arboriculturalists with a permanent record of the present vegetation and its growth patterns, but these assessments can also be used in identifying those areas that would benefit from maintenance and landscape planning. Different benefits include monitoring various plant and tree species to see which thrive in the given area, the locating of areas deficient in trees and other vegetation, the condition of the vegetation and trees throughout the year, and identifying trees needing maintenance. Even though the tree populations vary, cities with high tree populations such as Austin and Richmond can use these data bases as a source of information concerning tree maintenance and replacement; whereas, Iraan and Pecos planners can use the photographs to locate areas deficient in landscaping.

A record of this type of information in both cases is also an aid in identifying disease and insect pest outbreaks and potential areas to which they might spread. Early detection will limit the areas needing treatment. Such a system would help control outbreaks of disease and pests before they become epidemic. This data base would also serve to record past occurrences of any disease or pest endemic to the area. As a result, trees and plants susceptible to these problems could be avoided in future plantings.

Trees are an important aspect of the city and their destruction due to neglect would be disastrous. Replacement is costly and time consuming; therefore, tools that aid in the perpetuation of the existing tree populations should be examined to determine their application to everyday situations. This approach is one such tool which could greatly aid in the maintenance and planning of tree populations.

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