used to evaluate different programs with respect to the quantities of these elements and when applied.

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# THE ROLE OF MAPS, AERIAL PHOTOGRAPHY, AND IMAGE ANALYSIS IN CITRUS GROVE SURVEILLANCE AND APPRAISAL


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*Additional index words.* tree inventory, production estimates, damage assessment, wetlands distribution, property appraisals.

*Abstract.* **Properly prepared maps of citrus groves can play an important role in showing topographical, geological, and geomorphological anomalies that might affect grove management. Sequential aerial photographs taken at periodic intervals (biannually at least) with black and white (B & W) or aerial color infrared (ACIR) film, can reveal tree development (size), poor growth condition, and topographical characteristics. Aerial photographs, in combination with accurate grove maps, provide an excellent data base for comparisons with surveillance of the grove at desired intervals by grove managers or field inspectors. A sequential procedure is described whereby a citrus grove was located on a U.S.G.S. Quadrangle Sheet to clearly outline to the photographic plane the area to be covered in the photographic mission. Additional uses of the aerial photographs are described. When photographs were used in combination with maps, it was possible to measure productive and non-productive area, conduct tree counts, and make reliable yield estimates. Better and more accurate appraisals and management decisions were made with more available precise information.**

Among the many ways of keeping records in the production and management of agricultural crops, including citrus, one of the most used procedures involves use of grove sketches, maps, or diagrams (1, 2, 4, 10, 12, 13). These records are so common that not a great deal of thought is given to potential improvements or additional uses for them (3). Maps are an integral part of property records, deeds, and plat books of counties where agricultural areas such as citrus groves are recorded for assessing property values (11, 13). Included in these maps are property boundaries (3), wetlands areas, creeks, sinkholes, natural forests, and planting dates of citrus groves (2). Rootstocks and scions and other ancillary information is recorded in grove maps which can be used to determine how much has been invested in a particular block over a given period of time (2, 6, 7).

In recent years, the advent of aerial photography, aerial surveillance, and image analysis (5) have made grove sketches, maps, and aerial photographs more useful to those making management decisions (5, 8, 9). It is important for citrus grove owners and managers to be familiar with the impact that various types of maps have on the extraction of information from aerial photography and reconnaissance (6, 7, 8, 9). ACIR is also useful in appraising the value of groves and can reduce the time which an appraiser must spend in the field. The purpose of this study was to describe the need for various types of maps in locating a grove, why it is essential to outline an area in a U.S.G.S. Quadrangle Sheet, the use of image analysis of photographs, and how tree counts are useful in determining the dollar value of a grove.

### Materials and Methods

*Maps of test site.* A grove test site was selected in Polk County for the study because it has a variety of topographic characteristics such as wet and dry areas, ponds, creeks, and good citrus producing areas. Maps were obtained from: 1) Polk County Plat Book, 2) Florida General Highway Map, State Road Department, and 3) U.S. Geological Survey 7.5 minute Quadrangle Sheet Collection.

*Aerial and digitizing photography.* The experimental site was photographed by an aerial photographic company using a Wild RC-8 camera with a 6-inch focal length lens. Kodak Aerochrome 2443 Color Infrared film was exposed at a lens opening of f 5.6 and a shutter speed of 1/300th of a second. The Aerial Color Infrared (ACIR) film was processed by a commercial firm using a standard automated system and developed to positive transparencies (Fig. 1A).

Copies were made with black and white (B & W) 3.9 x 4.7-inch Panchromatic film and developed at the Photographic Laboratory of the Citrus Research and Education Center. Photographic prints were enlarged to 7.9 x 9.8 inches using glossy F2 Kodakbromide paper. A Linear Measuring Set System (LMS) (8) was used to digitize the entire Section 12 in the ACIR transparency and determine the productive (planted in citrus) and non-productive (fallow, wetlands, forest, housing, highways and railroads) areas observed in the transparency (Fig. 1B).

*Ground verification survey map.* A ground verification

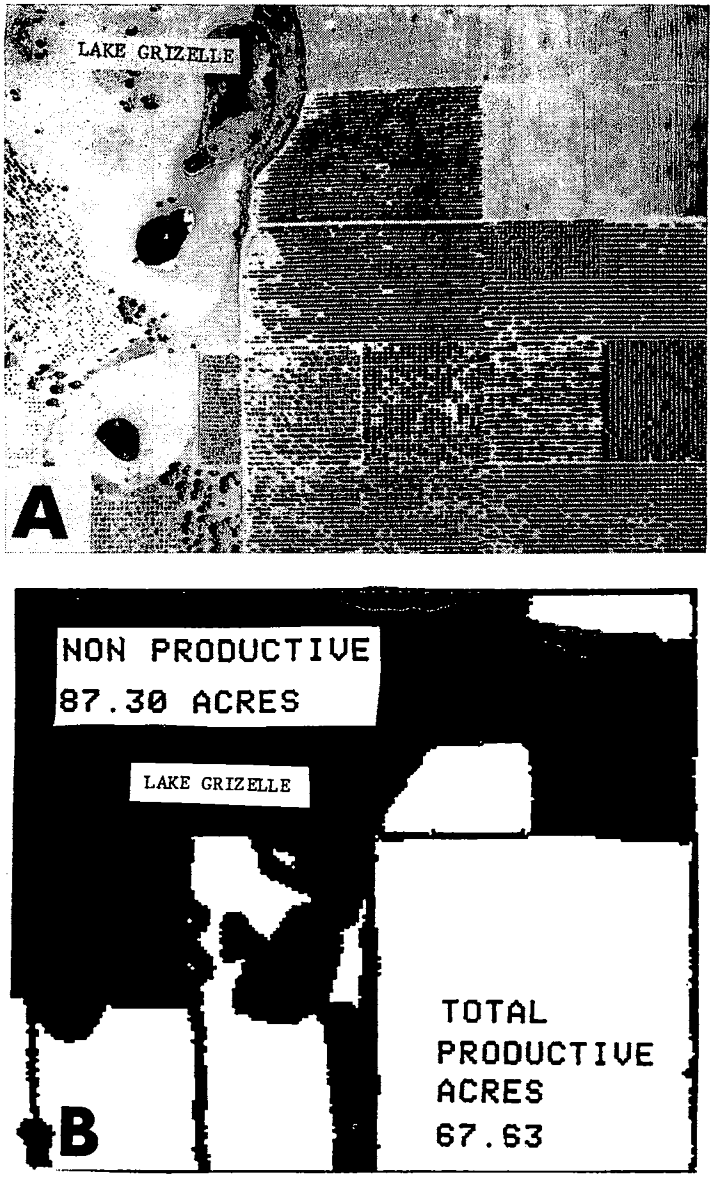



Fig. 1. (A) Black and white (B & W) print copied from an Aerial Color Infrared (ACIR) transparency of Lake Grizelle (Section 12) and surrounding test grove in Polk County. (B) Linear Measuring Set (LMS) printout of the digitized ACIR transparency, separating productive (citrus groves) from non-productive areas.

survey was made of the block to confirm the photointerpreted data and to make ground observations on soil moisture features that would affect growth of trees. Soil moisture was characterized in the area as low, adequate, or excessive. Tree maps (Fig. 2A) prepared from the ground survey were nearly identical to the ones created by photointerpretation.

*Photointerpretation.* A grid/cell system previously described (5) was used to set up the photointerpretation for each block. A standard cell size of 8 x 8 trees was used since it was the best fit for block planting distances. Once each block was interpreted, a summary table was prepared to add total counts of all the cells (Fig. 2). Cells are numbered from left to right and 1 to 10, with the first cell in the second row being number 11. As described in (5), any missing cells to the right of number 1 are ignored in the counting of the second row, so that the vertical cell numbering system from top to bottom starts with 1, followed by 11, 21, 31, etc. The system allows cell horizontal numbering by rows of 10. Any additional cells are assigned to another block.

A modified microfiche viewer was used to enlarge the tree images from the ACIR transparencies. This viewing system was an improvement over the microscope/light table described previously (5). A calculator was used to tabulate all the data, so it was necessary to modify the tree classification used in other experiments (5) to a numerical system (Table 1).

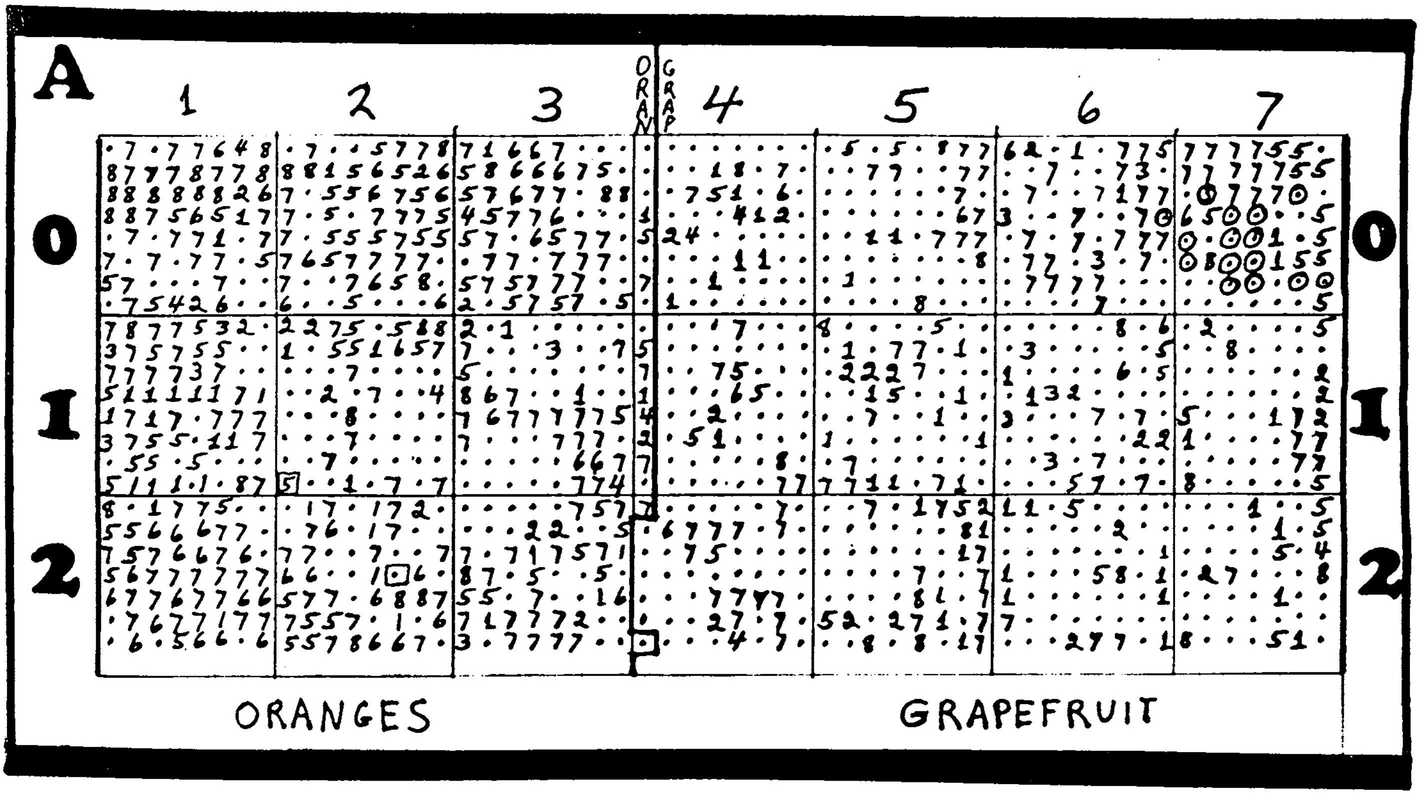
Table 1. Description of symbols used for grove mapping and interpretation of Aerial Color Infrared (ACIR) photography.

| Tree condition | Code |
|---|---|
| Large, healthy, normal foliage | (.) (=10) |
| Nearly healthy, thin foliage, 75% canopy | 1 |
| Poor health, dead twigs/branches 50% healthy canopy | 2 |
| Nearly dead tree, 25% healthy canopy, much dead wood, little fruit | 3 |
| Dead tree, perhaps with vines, tree location, and size | 4 |
| No tree (sometimes called skips or missing) | 8 |
| Replacement (also called reset) (trees less than 1 yr old) | 7 |
| Young tree (1 to 4 yr old) | 5 |
| Medium tree (canopy = 50% planting space) | 6 |

*Grove appraisal.* The data from Table 2 was used as an example of how an appraiser would utilize the data in assessing the value of a grove. The tree counts were separated into productive and non-productive categories. Each tree condition sub-category was rated according to production capability as compared to the normal productive trees within the citrus groves. The total trees per acre were then calculated by dividing the average trees per acre—58 trees per acre for the sample block. Using Savage's average historical yield table (14), total production for each tree condition subcategory was calculated by multiplying the total trees by the average production. Net returns per acre were then estimated by multiplying an average 3-yr price per box (9) by the total production and then subtracting the average non-irrigated grove care cost. The estimated net return was then divided by a capitalization rate (capital investment yield rate). The results yield an estimated value for the grove within each tree condition sub-category.

Table 2. Total number of orange and grapefruit trees in a block of a Polk County grove classified according to their size, stress condition, and number of skips. Results were first presented in Fig. 1A and 1B.

| Condition of tree | Space status/ canopy health | Total number in cells: Orange | Grapefruit |
|---|---|---|---|
| (.) (=10) | Large healthy | 200 | 460 |
| 1 | 75% healthy | 35 | 47 |
| 2 | 50% healthy | 14 | 21 |
| 3 | 25% healthy | 6 | 8 |
| 4 | Dead tree | 6 | 3 |
| 5 | Young | 69 | 34 |
| 6 | Medium | 51 | 8 |
| 7 | Replant (reset) | 158 | 96 |
| 8 | Missing tree | 31 | 17 |
| Total number of spaces | | 570 | 694 |
| Total number of productive Trees (% total spaces) (10 + 1 + 2 + 6) | | 300<br>52.63 | 536<br>77.23 |
| Total number of non-productive Trees (% total spaces) (3 + 4 + 5 + 8) | | 270<br>47.37 | 158<br>22.7 |




**B**

ORANGE

| CELL No | CLASS · 1 2 3 4 5 6 7 8 | TOTAL SPACES |
|---|---|---|
| 1 | 16 2 2 2 5 4 21 12 | 64 |
| 2 | 16 1 1 16 8 18 4 | 64 |
| 3 | 17 1 1 1 11 8 22 3 | 64 |
| 4 | 5 1 1 1 | 8 |
| 11 | 14 13 1 4 11 19 2 | 64 |
| 12 | 39 3 3 1 6 1 8 3 | 64 |
| 13 | 36 2 1 1 1 2 4 16 1 | 64 |
| 14 | 5 1 1 1 | 8 |
| 21 | 9 2 6 16 22 1 | 56 |
| 22 | 19 5 1 5 8 15 3 | 56 |
| 23 | 23 4 3 1 7 1 16 1 | 56 |
| 24 | 1 1 | 2 |
| | 200 35 14 6 6 69 51 158 31 | 570 |

GRAPEFRUIT

| CELL No | CLASS · 1 2 3 4 5 6 7 8 | TOTAL SPACES |
|---|---|---|
| 4 | 40 7 2 2 1 1 2 1 | 56 |
| 5 | 44 3 2 1 11 3 | 64 |
| 6 | 33 2 1 3 1 1 23 | 64 |
| 7 | 29 2 1 10 1 12 1 | 56 |
| 14 | 45 1 1 3 1 4 1 | 56 |
| 15 | 40 10 3 2 8 1 | 64 |
| 16 | 44 2 3 4 3 2 5 1 | 64 |
| 17 | 40 2 4 3 5 2 | 56 |
| 24 | 37 1 1 1 1 13 | 54 |
| 25 | 32 6 3 2 9 4 | 56 |
| 26 | 40 8 2 2 3 1 | 56 |
| 27 | 36 4 1 4 1 2 | 48 |
| | 460 47 21 8 3 34 8 92 17 | 694 |

Fig. 2. Handwritten partial sketch of a grove field survey used in recording photointerpreted data. (A) Partial group of cells recorded from test grove in Polk County. (B) Typical example of how the total number of cells were recorded on graph paper, summarized, and the total counts were made on a per block basis.

### Results and Discussion

Compiling information from the various types of maps available to the general public is not a hard task. However, it is necessary that individuals searching for information know the various levels of detail available in each class of map. The location of the test grove (Lake Grizelle) on the Bartow, Florida U.S.G.S. Quadrangle Sheet (N 2752.5-W 8145/7.5) was given to the aerial photographer so that he could precisely locate the grove and give a cost estimate of the photographic mission.

*Aerial photographs.* A great amount of detail and information concerning the test grove was observed in aerial photography, both ACIR transparencies and B & W copies. Considerable detail about the natural vegetation, forest, and the planted citrus trees could be detected. Soil moisture differences were easily observed in the ACIR transparency but could not be seen as well in the B & W print (Fig. 1A). The aerial photograph gave a synoptic view of the test grove, making it possible to observe conditions of other nearby groves. Some areas appeared to be in poor condition from water damage due to the proximity to lakes, a fact which was confirmed by a field verification visit (Fig. 2A).

The measurement of productive and non-productive areas with an image analyzing system such as the LMS (Fig. 1B) increased the value of the aerial surveillance considerably. In addition, it was comparatively inexpensive. It would be very costly for a ground survey crew to obtain such measured data. Measuring areas with the LMS could play an important role in keeping the cost of surveys down as well as increasing the accuracy of measuring productive and non-productive areas.

Although a great deal of information was obtained about the test grove (Fig. 1A), knowledge of nearby groves was helpful in considering other reasons why certain areas of the test grove had specific problems. In a number of the nearby groves, there were indications that there was excessive soil moisture in areas where trees had not grown well. These indications could only be confirmed by sequential photography during different seasons of the year to establish possible water level changes when compared with the rest of the area observed. The results of the photointerpretation were very close to those of the ground verification (Fig. 2). This suggests that if the same individuals conduct both the photo-interpretation and the ground survey, small differences in results can be expected. Although the technology described here has been reported previously (5, 6, 7, 10), the results of this combination of ACIR, image analysis, tree counts, and production costs, show what can be done with ACIR.

*Ground verification map.* Only a portion of the block map is illustrated in Fig. 1A and B to show actual tree counts according to the grid/cell method (6). The summary for the whole block is shown in Fig. 2B and Table 2. Missing and stressed trees were detected in Cells 1 and 3 and many resets were observed in Cells 7, 11, 22, and 23 near the border of the block and in the lower portion of the block but no definite pattern of loss could be detected due to the low number of trees involved. Based on the ratio of productive versus non-productive trees (52.63 to 47.37%), the sweet orange [*citrus sinensis* (L.) Osb.] trees (Cells 1, 2, 3, 11, and 12), did not appear to be in good condition. The grapefruit [*C. paradisi* Macf.] trees (Cells 4, 5, 6, 14, 15, 16, 26, and 27) were in a much better condition where a productive percentage of trees was 77.23%.

*Grove appraisal.* The results of assessing the value of the test grove were prepared by analyzing the data in Table 2 and combining the information on estimated acreage, yield, and net returns (Table 3). The fully healthy, mature productive acreage had a total estimated value of $19,288 or $5,590 per acre. The other productive sub-categories were calculated in the same overall value of productive acreage estimated to be $23,342 or $4,515 per acre. Likewise, the nonproductive acreage value was calculated using the value for the land only—$1,000 per acre. Overall value of the sample grove was estimated to be $28,000 or $2,850 per acre was calculated by dividing the overall value by the total

## Conclusion

Maps of citrus groves are an important tool in grove management. Properly prepared maps can aid the production manager by knowing the tree count and tree condition of a citrus grove. ACIR transparencies provide the means for accurate tree counts and rating tree condition as to productivity capability. Image analysis of the photography rapidly delineated the productive and non-productive areas of the grove. By combining the use of grove maps and the data collected from ACIR transparencies with image analysis, an appraiser can estimate the dollar value of a citrus grove.

Table 3. Estimated acres, yield, net returns, and grove value—sample 'Valencia' sweet orange block.

| Code condition of tree | Production capability rating (%)[z] | Total tree spaces[z] | Total tree acres[y] | Average tree yield (boxes)[x] | Estimated total yield (boxes)[w] | Estimated net returns[v] | Estimated value capitalized at 17%[u] | Estimated value per acre[t] |
|---|---|---|---|---|---|---|---|---|
| Productive | | | | | | | | |
| 10 | 100 | 200 | 3.45 | 4.60 | 920 | $3,279 | $19,288 | $5,590 |
| 1 | 75 | 35 | 0.60 | 3.85 | 135 | 435 | 2,559 | 4,265 |
| 2 | 50 | 14 | 0.24 | 2.30 | 32 | 55 | 324 | 1,350 |
| 6 | 50 | 51 | 0.88 | 2.30 | 117 | 199 | 1,171 | 1,330 |
| Sub-total | | 300 | 5.17 | | 1,204 | $3,968 | $23,342 | 4,515 (overall) |
| Non-productive | | | | | | | | |
| 3 | 0 | 6 | 0.10 | — | 0 | 0 | $ 100 | $1,000 |
| 4 | 0 | 6 | 0.10 | — | 0 | 0 | 100 | 1,000 |
| 5 | 0 | 69 | 1.19 | — | 0 | 0 | 1,190 | 1,000 |
| 7 | 0 | 158 | 2.73 | — | 0 | 0 | 2,730 | 1,000 |
| 8 | 0 | 31 | 0.54 | — | 0 | 0 | 540 | 1,000 |
| Sub-total | | 270 | 4.66 | | 0 | 0 | $4,660 | 1,000 |
| TOTAL | | 570 | 9.83 | | 1,204 | $3,968 | $28,002 | $2,850 |

[z]Refer to Table 2.
[y]Total trees + 58 trees per acre; tree spacing in sample 'Valencia' orange block is 25 ft x 30 ft or 58 trees/acre.
[x]Average historical yield for late oranges (14); box = 1-3/5 bushel equivalent.
[w]Total trees x average yield per tree.
[v]Estimated total boxes x 3-yr average price per box (9) less average non-irrigated grove care costs (12).
[u]Capitalization rate was obtained from selected grove sales in Polk County.
[t]Estimated total value + total tree acres.

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