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# AERIAL COLOR INFRARED PHOTOGRAPHY— A MANAGEMENT TOOL[1]

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*Abstract.* **Aerial color infrared (CIR) photographs of a citrus grove become a permanent record of a specific period of time of the trees and grove conditions, giving a synoptic overview of large areas of the grove, pinpointing numerous problems and conditions in single photographic frames. Trees under slight stress were detected in CIR film 13 months before they were found in ground surveys. The information recorded in the aerial CIR photograph was transferred by a photointerpretation (PI) and cell registration system to computer compatible format for storage, analysis, and retrieval. A computer program was developed to print out the number of dead, missing, resets, young, medium, healthy, and diseased trees of various degrees. Printouts were obtained for the entire grove and for an individual cell or section of the grove. The information obtained from the CIR is useful in purchasing nursery trees, reducing tax assessments, tree inventories, and the planning of tree removal.**

Aerial color infrared film (CIR) has been used to emphasize differences between objects that are quite similar (5). CIR film such as Eastman's 2443 emphasizes differences in infrared reflection but not thermal or temperature differences.

Patterns in crop variation caused by nonuniform fertilization, spraying, irrigation, drainage, soils, weeds, grasses, vines, disease, and insect damage often have been more evident from aerial photographs than they have been from the ground (10). Variation in crop patterns show up as changes in the amount of spectral reflectance. Any reflection change in green, the visible portion of the spectra, may be due primarily to reduction or loss of chlorophyll. Variation in the reflection of red may be caused by damage or changes in internal leaf structure, air in the intercellular spaces, and spongy mesophyll cells. In some cases, leaf structure influences the near infrared area but the amount of water in the tissue is the dominating factor (9). The first change that may occur in diseased and dying foliage is a decrease in the near infrared reflectance which may take place before any visible change can be noticed (7). Early in remote sensing research, it was determined that the greatest amount of foliage reflectance was in the near infrared region of the electromagnetic spectrum.

Norman and Fritz (8) pioneered the use of CIR in detecting stress in Florida citrus trees in 1965. In the following years Blazquez et al. (3) used CIR in mapping citrus groves in 1978, and Edwards et al. (6) in 1979 showed the use of CIR in counting healthy, diseased, missing, and replacement trees, and observed indirectly the differences between rootstocks and budwood sources.

Aerial color photography has been reported as a practical tool that can provide an inventory of the tree spaces and tree condition (4) that can be stored in a computer for future retrieval. The retrieval can be a printout of the grove map with a row/tree listing according to categories or give the total number of producing trees in the grove. Inventory of nonproducing trees can be used to reduce taxes and to give a better handle on ordering nursery trees and planning tree removal (1, 2).

The purpose of this paper is to report the agreement between photointerpretation of a spring CIR transparency and subsequent ground verifications suggesting that it is possible to observe stress conditions of a tree with CIR prior to visual symptoms of stress.

## Materials and Methods

### *Test Grove Location*

The grove selected for photographic experimentation (Gapway No. 3) is located in Township 27S, Range 26E, Section 26, Polk County. The grove, planted on rough lemon rootstock spaced 30 ft x 30 ft has been used extensively for

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young tree decline transmission experiments and pest management trials. Varietal plantings were made without a definite pattern and the grove has irregular borders. The 38.5 ha (85 acres) grove has 'Hamlin' oranges planted in a large St. Lucies series, sandy area soil with 'Valencia' oranges, and 'Marsh' grapefruit trees planted in adjacent areas. 'Hamlin' trees are *inter*planted in a north-south direction with smaller 'Hamlin' trees resulting in a hedge row.

### *Aerial Photography*

Aerial photographs were taken using a 23 cm x 23 cm (9" x9") Zeiss electric color aerial camera, with a 30 cm (12 inch) focal length lens and a "C" (yellow) color compensating filter, connected to an intervelometer. The camera was powered by the electrical system of an Aerocommander aircraft.

The first mission was flown with the 30 cm focal length lens on April 4, 1978. Photographs were taken vertical from an altitude of 1200 m (4000 ft) using Kodak Aerochrome 2443 infrared film (CIR), giving a scale of 2.54 cm (1 inch) = 102 m (333 ft). The photographs were flown using a forward lap of 60% for a total of 10 photographs per flight. Each color transparency covered 94.5 ha (208 acres) with a forward net gain of 26.3 ha (58 acres). Processing was done with the required chemicals in a standard Versamat color processing unit. The processing was done by the topographic section of the Florida State Department of Transportation at Tallahassee, Florida.

### *Photointerpretation*

Before photointerpretation (PI) can begin, it is necessary to know where the photos are in relation to the grove. Flight lines are marked on a U.S.G.S. topo map or the Crop and Livestock Reporting Services' photo or blue line prints which show enough physical land structures or grove borders to find the start and end of the flight lines. To facilitate the PI this grove was marked off in cells of 8 trees x 8 trees as described by Blazquez (3).

PI was done over a light table made with 4 cool white fluorescent lamps 1.21 m (48 inches) or 0.61 m (24 inches) long. These lamps are under a smooth milk white plastic diffuser.

The transparency is viewed with a 4½ inch reading glass or a 3 to 4X illuminated magnifier lamp or stereomicroscope with a 10X wide field eyepiece and 2.5 to 280X magnification range.

Interpreting and recording the results can be done by a single individual but with a team of 2 the number of trees read can be increased. The recorder uses a mylar overlay on a black and white photo enlargement of the grove or on graph paper marked off in cells with the same tree spacing as the grove.

When the PI was completed, the results were summarized in a table and inputed into a computer. A Fortran program was written for the General Automation SPC-16/65 computer, which prints out maps according to tree categories. The categories are healthy, medium, young, missing, replants, and stressed. The stressed trees are rated on a scale of 0 to 4 (0 being healthy; 4 being dead). The maps have 2 symbols: (@) for the category type and (–) for the other trees. It also prints out a map of all trees dead and declining and a summary of the number of trees in each category and a row tree listing for each category map.

Color infrared photographs were made over the Gapway grove in April 1978. Visual evaluation, ground truth (GT) maps were made in March 1978, November 1978, and again in January 1979.

Date from the ground truth maps of March 1978, January 1979, and the photointerpretation of April 1978 was placed in the computer. Maps of each were printed out along with the row tree notation for each category and a summary of the categories. Since the medium size trees were not mapped as a separate category in the 78 GT, the 79 GT, and the 78 PI summed these with the healthy trees.

Nine 64 tree cells and two 61 tree cells were selected at random to see how well the April 78 PI forecast the grove condition in the May 79 GT.

The mean number of trees was calculated for each category from the 11 cells for the 78 GT, the 78 PI, and the 79 GT (Table 1).

Two cells of 78 PI that agreed well with the 79 GT are shown in Table 1 as well as 2 cells of the 78 PI that did not agree with the 79 PI.

## Results

The mean number of trees was calculated for each category from the 11 cells. In all categories except the missing and dead trees, the 78 PI was nearer the 79 GT than the 78 GT (Table 1).

Table 1. GT and PI of No. trees in each category.

| Cell | Date | | | | Healthy | Young | Replant | Stress rating 1 | 2 | 3 | 4 | Missing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean No. of trees | March | 23 | 78 | GT | 50.91 | 5.27 | 2.91 | 2.73 | 0.91 | 0 | 0.09 | 0.63 |
| in 11 cells | April | 6 | 78 | PI | 43.82 | 4.91 | 2.91 | 7.91 | 1.46 | 1.46 | 0.27 | 0.72 |
| cells | May | 14 | 79 | GT | 40.00 | 4.36 | 2.36 | 10.82 | 2.46 | 0.91 | 0.00 | 2.55 |
| | March | 23 | 78 | GT | 60 | 0 | 0 | 1 | 0 | 0 | 0 | 3 |
| 46 | April | 6 | 78 | PI | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | May | 14 | 79 | GT | 51 | 0 | 0 | 9 | 1 | 0 | 0 | 3 |
| | March | 23 | 78 | GT | 46 | 9 | 5 | 4 | 0 | 0 | 0 | 0 |
| 43 | April | 6 | 78 | PI | 44 | 5 | 5 | 5 | 2 | 3 | 0 | 0 |
| | May | 14 | 79 | GT | 33 | 4 | 2 | 16 | 3 | 3 | 0 | 0 |
| | March | 23 | 78 | GT | 55 | 2 | 2 | 2 | 1 | 0 | 0 | 2 |
| 55 | April | 6 | 78 | PI | 59 | 0 | 0 | 2 | 1 | 0 | 0 | 2 |
| | May | 14 | 79 | GT | 59 | 0 | 0 | 2 | 1 | 0 | 0 | 2 |
| | March | 23 | 78 | GT | 52 | 8 | 3 | 1 | 0 | 0 | 0 | 0 |
| 22 | April | 6 | 78 | PI | 38 | 9 | 3 | 14 | 0 | 0 | 0 | 0 |
| | May | 14 | 79 | GT | 38 | 7 | 3 | 15 | 1 | 0 | 0 | 0 |

GT = Ground truth.
PI = Photointerpretation.

Table 1 also shows the results of cells 46 and 43. Here the 78 PI was nearer the 78 GT. In cells 55 and 22, the results of the 78 PI is near the 79 GT.

From a summary of the computer maps, as in the mean number of trees in the 11 cells, the 79 GT was nearer the 78 PI than the 78 GT. The 78 GT showed 78% healthy and medium size trees. The 78 PI showed 63% and the 79 GT showed 64% healthy and medium size trees (Table 2).

Table 2. Summary of computer map printout of Gapway grove.

| Categories | % of total spaces | | |
|---|---|---|---|
| | PI April 6 78 | GT March 23 78 | GT May 14 79 |
| Healthy + medium, •, Λ | 63 | 78 | 64 |
| Productive = •, Λ, 1, 2 | 81 | 92 | 82 |
| Nonproductive = 3, 4, x, R, – | 19 | 17 | 18 |
| Nursery order = 3, 4, x | 7 | 5 | 8 |
| Predicted nursery order = 1, 2 | 18 | 5 | 18 |

The producing trees are the sum of the healthy, slightly stressed trees, 1's, and the moderately stressed trees, 2's. The results show 81% productive from the 78 PI and 82% from the 79 GT while the 78 GT shows 92%.

The nonproductive trees are the sum of severely stressed trees, 3's, the dead trees, 4's, the missing and the young trees, and replants or 19% as shown by the 78 PI and 18% by the 79 GT. The 78 GT showed 17% nonproductive.

The trees that need a nursery order placed are for the dead and missing trees. The 78 PI calls for 7% and the 79 GT says 8% while the 78 GT calls for an order of only 5%.

Groves affected with the stress of young tree decline and having trees in the moderate (1) and slight (2) state of stress will probably need replacement in 2 to 3 years. Assuming the 1's and 2's in this grove will need replacement in 2 to 3 years, a future nursery order would be 18% of the grove according to the 78 PI. This is confirmed by the 18% of the 79 GT and not the 5% as the 78 GT noted from Table 2.

## Conclusions

Interpretation of the color infrared photography shows the number of tree spaces in a block and the condition of each tree. It would appear that comparing the PI to the GT provides a detection method of tree stress about one year in advance of visual symptoms.

PI and GT data can be inputed to a computer to produce maps and listings of the spaces and its condition. The conditions are healthy, medium size, young, stressed in a 0-4 range, missing and replaced.

The conditions may be summarized to show percentage of producing trees, nonproducing trees, and this information can be used as evidence for a more realistic appraisal for taxation.

Knowledge of tree condition gives a grower means of early detection of grove problems as well as a more realistic reset needs from the nursery.

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# CITRUS GROVE PRICES AS DETERMINED BY DISCOUNTING EXPECTED INCOME AND COSTS


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*Abstract.* **Citrus groves are a complex investment: deciding whether or not to buy a grove requires an assessment of several forces that may change in the future. This paper offers a flexible procedure for estimating the effect of such things as appreciation in land values, changes in the expected income from future yields, level of desired rates of return on investment, mortgage credit terms and income tax levels on the amount that can be paid for a grove. Potential grove buyers can use their own projections about an uncertain future to help them estimate the maximum they can pay for a grove. The estimated maximum bid price for a grove may be higher or lower than the price at which it is being offered for sale. If the estimated price is higher than the asking price, and the buyer is content with his estimates of future returns in citrus, then he should make the purchase. If, as frequently happens, the estimated bid is lower than the asking price, the input data may be changed until the model reproduces the asking price. This indirect procedure makes it plain what conditions will have to be in the future if the asking price is to be paid.**


The traditional formula for estimating land values is $V = I/r$, where V is the estimated land value; I is expected