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Multispectral Sensing of Citrus Young Tree Decline†

Healthy trees were discriminated from diseased trees with an overall accuracy of 89 per cent.

Abstract: *The Laboratory for Applications of Remote Sensing* **(LARS)** *computer program at Purdue University has been used to analyze multispectral sensing data to identify and map citrus trees affected with young tree decline. The overall accuracy of the method for determining healthy and diseased trees is 89 per cent using data collected at 820-880 nm from aircraft at 1500-feet altitude.*

Introduction

The loss of citrus trees in Florida due to young tree decline *(YTD)*, also called sand hill decline, has been known since 1964[1]. The decline is of undetermined etiology and losses have been most prevalent on varieties of *Citrus sinensis* (L.) Osbeck: Valencia, Pineapple, and Hamlin sweet oranges budded on *C. jambhiri* Lush., rough lemon rootstocks. Prevalence of the decline has been steadily increasing since 1964, and estimates on rate of spread of the disease vary from 1 per cent per year in groves where it first appears to 22 per cent per year in groves where the disease has been established for over five years[2]. *YTD* is of major importance to the Florida citrus industry since approximately 500,000 acres, or 60 per cent of the Florida citrus acreage, are budded on rough lemon rootstock.

To determine the extent of tree loss due to *YTD* and to survey visually 500,000 acres of citrus would be a slow and cumbersome operation. Studies have been made to test instrumental methods to objectively diagnose *YTD* and make rapid surveys of large areas[3]. Of the techniques tested, spectral reflectance and photographic methods seemed to be most practical for making such a survey. Therefore, studies have been started to test a Multispectral Sensing approach.

Methods

Multispectral Sensing *(MSS)* remote sensing investigation was made with the cooperation of *NASA* Kennedy Space Center, and Manned Spacecraft Center, Houston, on a block of Valencia orange trees budded on rough lemon rootstock, eight years old near Fort Pierce, Florida. Trees were visually graded zero for healthy, 0.5 for slight or first stages of decline, 1.0-1.5 for moderate, and 2.0-2.5 for severe or advanced stages of the disease. Of 336 trees in the test area, 208 were healthy, nine graded 0.5, 59 graded 1.0, 34 graded 1.5, 10 graded 2.0, and 4 graded 2.5. Ten were replants and two trees were missing.

Spectral reflectance measurement was first made of individual leaves from each grade of decline. Leaves were sent to the Manned Spacecraft Center at Houston where they

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were analyzed under a diffused quartziodine tungsten source in an integrating sphere[4]. Spectral reflectance data was obtained from a Cary-14 RI spectrophotometer with a gonioreflectometer attachment.

Instrumental ground truths of the tree crown were also made in the field with an EG & G spectroradiometer system mounted in a cherry picker basket positioned 20 feet above the tree.

For the second phase of the study, an airborne multispectral sensing system *(MSS)* was tested[5]. The *MSS* data were obtained using the *NASA*, Johnson Space Center, C-130 aircraft equipped with a 24-channel spectral analyzer. Flights over the test area were made at altitudes of 1,500, 10,000, and 15,000 feet. Data used in this paper were obtained from 1,500 feet. This data was taken between the hours of 10:00 A.M. and 2:00 P.M. on a cloud-free day in the first week of March 1973. March and November are the times of the year when the trees show the greatest stress. The 24 discrete spectral bands covered spectral regions from 0.34-13 μm; smallest band width being 0.4 μm and largest 1 μm. Bands used in this work were 0.53-0.58, 0.72-0.76, 0.77-0.81, 0.82-0.88, 1.05-1.1, and 1.2-1.3 μm. Reflectance intensity from sensors was recorded on magnetic tape, and was digitized using the *LARS* program, at Purdue University. Digitized data were processed at the Johnson Space Center.

The first step in the processing data was to locate tree signals obtained in the *MSS* measurements. To do this, a printout was first obtained of the spectral range where all trees would have values differing from values identifying roads, waterways, bare ground, and vegetative ground cover. A set of symbols was assigned to separate tree spectral values from all other spectral values, then a set of coordinates was obtained for each tree in the training area on the *MSS* data tape. A 4-by-4 data point square was printed out for each of the trees (Figure 1).

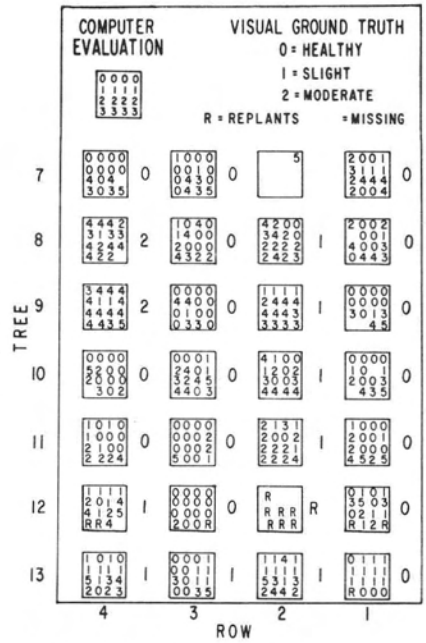


FIG. 1. *MSS* printout and visual ground truth evaluations of citrus trees affected by *YTD*.

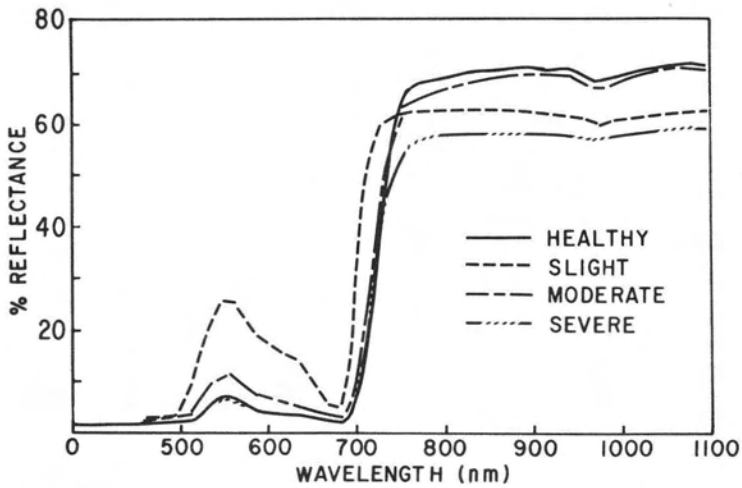


FIG. 2. Laboratory reflectance spectra from citrus leaves from healthy and *YTD*-affected trees.

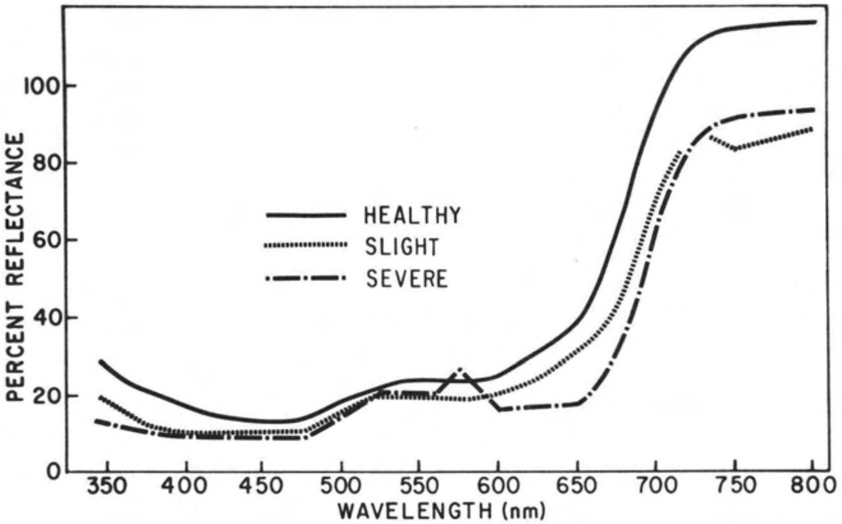


FIG. 3. Field radiometer reflectance spectra from tree crowns of healthy and *YTD*-affected citrus trees.

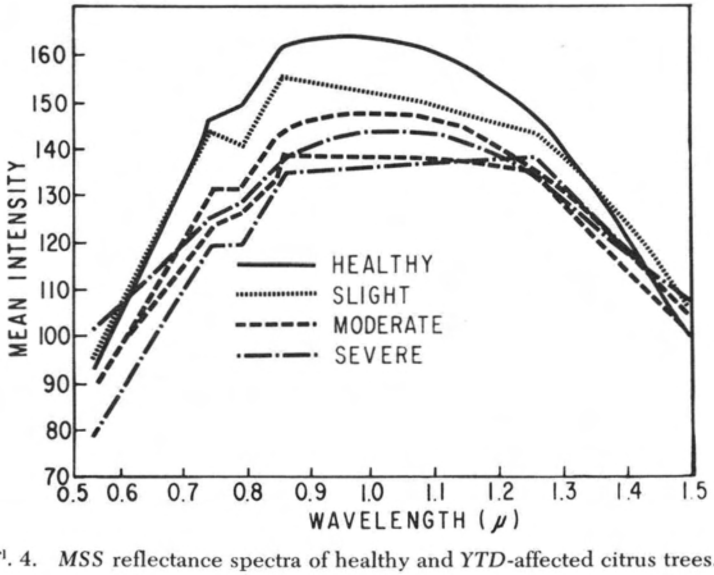
RESULTS

Measurable spectral reflectance intensity differences between healthy and *YTD*-affected citrus trees were observed. On a single leaf basis, there were differences in the 500-600 nm wavelengths and in the 700-800 nm wavelengths. Early phase of decline showed maximal differences in the 500-600 nm wavelength area (Figure 2).

In the field, the difference was demonstrated in the crown of the tree using a telespectralradiometer. Spectra from the field radiometer were similar to the laboratory spectra, but not so pronounced in the 500-600 nm area (Figure 3).

Although the mean intensity, mean wavelength from the *MSS* data, differed somewhat from the laboratory and field spectra, the calibration curves from the *MSS* data clearly differentiated between healthy and the various stages of *YTD* (Figure 4). The best wavelengths for detecting *YTD*-affected trees with *MSS* were in the 1.05-1.1 μm wavelength.

Of the 336 trees in the test area, 205 were used to calibrate the computer; the remaining 131 trees composed of 84 healthy trees,



f^l. 4. *MSS* reflectance spectra of healthy and *YTD*-affected citrus trees.

three in the first stages of *YTD* and 44 trees in the second and third stages of *YTD* were analyzed. The 44 trees in the second and third stages of *YTD* were purposely grouped together to improve the computer performance.

Of the 84 healthy trees, 75, or 89 per cent, were selected by the computer as healthy. The three trees in the first stages of decline were selected by the computer for 100 per cent of this group. Of the 44 trees (second and third stages of *YTD*) grouped together, 31 were judged to be in some stage of *YTD* by the computer. From the 131 test trees, the program made 109 correct decisions for an average of 83 per cent.

Data were reanalyzed by regrouping 318 trees in the test plot into healthy and decline. This time only 24 of the trees were used to train the computer to detect between healthy and all stages of *YTD*-affected trees.

The mean intensity, mean wavelength values for the two categories resulted in a calibration curve similar to Figure 4, but with an increase in the intensity difference between healthy and decline trees. In this regrouping, the wavelength showing the greatest difference for detection of YTD-affected trees in comparison to healthy trees was in the range of 0.82-0.88 μm (Figure 5).

With the calibration data of the 24 trees stored in the computer's memory, the remaining 294 trees were evaluated. Of the 178 healthy trees, the computer correctly determined 162 or 91 per cent. Of the 116 *YTD*-affected trees, the computer picked 100 or 86 per cent. In all, 262 correct decisions were made by the computer for an overall performance of 89 per cent correct decisions.

Discussion and Conclusions

The ground truth was made from one evaluation where the *MSS* evaluation was made from 16 evaluations over the tree's top. From the 16 points on each tree of the computer printout, there was a nonuniformity of numbers. That is, a zero or healthy tree did not show 16 zeros. The numbers of the 16 points represent the reflection signal intensity from 0-6, zero representing a signal from a healthy part of the tree and increasing numbers indicating a departure from healthy. Tree 12, Row 3 of Figure 1 has 14 zeros, one 2, and one R for a zero ground truth. Tree 8, Row 4 of Figure 1 shows seven 4's, two 3's, three 2's, and one space missing for a ground truth of 2.

The numbers other than zero for healthy may be a clue of previsual detection of *YTD*. For trees, other than healthy, to show computer determined numbers different from their visual grade indicates the importance of having an experienced person making the ground truth judgments in the grove.

From *MSS* magnetic data tape, it was possible to train or program a computer with the *LARS* program to make determinations with a high degree of accuracy regarding the condition of individual citrus trees. The wavelength range for the *MSS* detector to achieve this accuracy was 0.82-0.88 μm from aircraft flying at 1,500 feet.

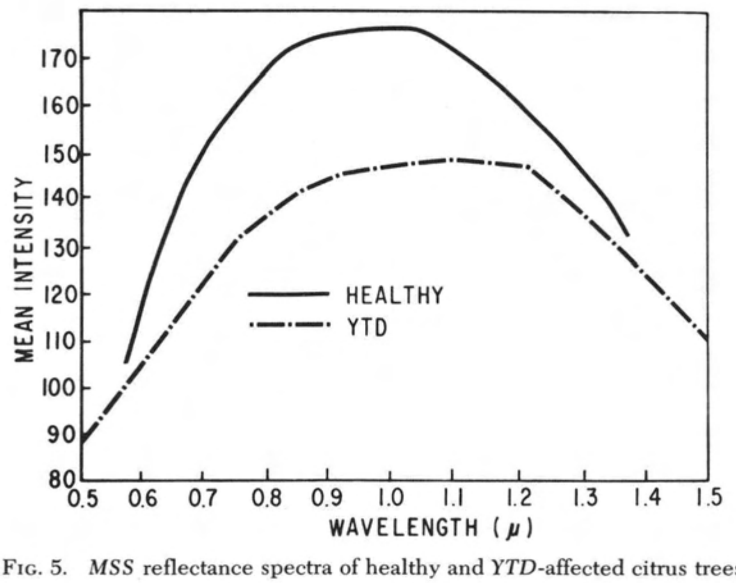


FIG. 5. *MSS* reflectance spectra of healthy and *YTD*-affected citrus trees.

It seems likely that with further refinements in the scanning and programming of the *MSS* data, the accuracy of instrument determination regarding tree health could be improved. The ability to make accurate instrument determination of tree health and therefore productivity and to make surveys from aircraft would be of considerable value to individual citrus growers as well as to the citrus industry at large.

References

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Forum

Stereoradar

Dear Editor:

The February 1975 issue contains an interesting contribution by G. L. Bair and G. E. Carlson on "Height Measurement with Stereoradar." The simulated side-looking radar images really were very illustrative and appealing for evaluation of stereoviewability of various SLAR image pairs.

However, I feel that it would have been essential for the paper to contain a remark putting the applicability of the proposed technique for single flight stereo SLAR into proper context: This technique is valid only with brute force SLAR, and cannot be employed with synthetic aperture radar. It is, however, the synthetic aperture radar which is at present exclusively used for civilian mapping; and if side-looking radar has any significant future for non-military use, it now seems that this will be mainly with synthetic aperture.

With this type of sensor, the (synthetic) radar antenna beam is always perpendicular to the flight path or orbit, provided that image correlation is with respect to the zero Doppler frequency; or the beam can be made conical, if correlation is with respect to a Doppler frequency different from zero. Other beams are not possible. Two conical beams, however, cannot produce a valid single-flight stereo system. This was recognized in an earlier paper by Dr. G. E. Carlson[1] and, in a somewhat different terminology, also in a contribution that I published in English in the *Austrian Journal of Surveying*[2]. Incidentally, I discussed and analyzed in that paper a single-flight stereo configuration for brute force SLAR that employed radar antenna beams tilted around the across track axis (pitch or photogrammetric φ). One can still think of a number of other single-flight stereo configurations, but none of these would be valid with synthetic aperture SLAR. In order to obtain a useful stereo parallax from overlapping imagery with such a type of SLAR system, one will have to rely on separate flights or orbits.

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[1] Carlson, G. E., "An Improved Single Flight Technique for Radar Stereo," *IEEE Trans. on Geoscience Electronics*, GE-11, No. 4, Oct. 1973.

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