Fig. 6. Progression of soil moisture extraction patterns, March-April, 1975.

suction as well as the point 86 inches from the tree at the four foot depth. During the week that followed, 1.50 inches of rainfall/irrigation occurred on March 16 and 17. Tensiometer measurements on March 22, 5 days after irrigation, revealed that soil at 6 inch depth except at the midpoint between trees was still below 20 centibars suction. The tensiometer at 12 inch depth closest to the tree was indicating 22 centibars of suction on March 22. It is quite possible that the irrigation application of March 17 did not apply a proportionate amount of moisture to soil under the tree foliage canopy (1, 2). Also, moisture removal at the 4-foot depth appears to be continuing. Rainfall during the week that followed was 1.04 inches with 0.85 inches occurring on March 28, the day before tensiometer measurements were made. This rainfall caused the soil moisture suction to drop below 20 centibars at the 6 and 12 inch depths at all distances from the tree. Since moisture extraction at depths of 2 feet or greater was continuing and expanding, it does not appear that this rainfall added significant moisture to soil of this zone. During the following week, without rainfall or irrigation, most of the soil under the tree foliage canopy returned to soil moisture suctions greater than 20 centibars.

Summary and Conclusions

Starting at field capacity, moisture is first extracted from soil near the center of the tree and at shallow depths. Extraction progresses radially and downward with respect to time. If moisture availability is not a restraint, moisture extraction seems to be more concentrated in the surface soil and near the sandy clay substratum, with somewhat less activity at the 2 and 3 foot depths. The results of this study suggest that drip emitters should be placed near the center of the tree so that water is applied where it is first deficient.

Literature Cited


IMAGE ANALYSIS OF MULTISPECTRAL SENSING DATA OF YOUNG TREE DECLINE OF CITRUS

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Abstract. Image analysis of multispectral data of citrus trees visually rated as having Young Tree Decline (YTD) are reported here. The multispectral data was taken in areas where spectral differences correlate with disease ratings. An alphanumerical printout of the diseased trees was made from a ratio of spectral range 0.800-0.890 μ to 0.500-0.600 μ and from the thermal spectral range 8 to 14 μ. The ratio technique agreed with the visual ground truth ratings 86% of the time. The thermal range showed an 87% agreement with the ground truth. The lack of repeatability in the method will be worked on to make the technique reliable.

The loss of citrus trees to the mysterious malady, Young Tree Decline (YTD), has been known for more than 12 years (1). There has been no rapid method developed to determine the extent of the disease. The estimate of the rate of spread is from 1% per year in groves where it first appears to 25% per year in groves where the disease has been established for over 5 years (2).

To develop a rapid method to map the diseased trees, NASA at Kennedy Space Center and the University of Florida Agricultural Research and Education Center at Lake Alfred are working together to develop a multispectral data system to accomplish this.
Materials and Methods

Multispectral data were made on a block of 'Valencia' orange trees, budded on rough lemon rootstock, north of Lakeland, Florida. The trees varied in age from replants, 8 years, 20 years, and some 45 years old. Trees were visually graded 0 for healthy, 1 for slightly diseased when the tree has small leaves standing in a rosetted pattern and no or not much new growth and may or may not have a zinc-deficiency pattern on some leaves. A grade 2 has all of the features of a grade 1 plus a thinning of the canopy and deadwood in the tree but still producing a fruit crop though many of the fruit may be small. A grade 3 is a tree that is no longer producing, very thin foliage, lots of deadwood, plus all the features in grades 1 and 2.

The data were made from Kennedy's NASA-6 aircraft flying at 1500 ft and equipped with a 11-channel spectral analyzer made by Daedalus Enterprises, Inc. The flights were made on a cloud-free day between 10:00 a.m. and 2:00 p.m. during the 1st week of March 1976. The 6 channels used in this study were channels 4, 0.500 to 0.550 μ; 5, 0.550 to 0.600 μ; 7, 0.650 to 0.690 μ; 8, 0.700 to 0.790 μ; 9, 0.800 to 0.890 μ; and 12, 8 to 14 μ. These are some of the areas of the electromagnetic spectrum that have shown differences with disease ratings (8, 4). The reflectance intensity data from the sensors of the multispectral analyzer were recorded on a FM magnetic tape recorder and read directly into the Image 100 which digitized the data. This digitized data was then processed in General Electric's Image 100.

The Image 100 (5) is designed and built by General Electric Company, Ground Systems Department, Space Division, Daytona Beach Florida. It is a multispectral image analyzer which extracts thematic information (spectral class types) from imagery and performs signature analysis. The unit consists of an input scanner unit, light table, video camera, a filter wheel, magnetic tape drives, an image analyzer console with a Cathode Ray Tube (CRT) display, a line printer, and a graphics display terminal. Once the multispectral digital data has been entered into memory, the operator can view the image in all or part on the CRT. He then can use many basic and specialized computer programs written for this instrument and called for with the graphics terminal.

Some of the terminology used with this instrument is as follows:

Pixel. A picture element or an observation point on the scene. A scene is composed of 512 x 512 pixels.

Channel. A set of pixels that represents the radiometric response of the sensor of a particular micron wavelength range. A max of 5 channels may be used at 1 time.

Histogram. The frequency distribution of pixels plotted against density level. 0 represents 0% transmission and 255 represents 100% transmission.

Signature. The characterization of a pixel, or pixels, based on its density distributions among the channels.

Alarm. After a signature has been obtained from a training area (a No. 2 diseased tree in this case), all other areas of the same signature will be displayed the same on the CRT.

When the frame of interest is displayed for the channel or channels to be studied, an area of the grove was enlarged so each tree could be easily seen. The ground truth was then annotated on each of the trees in the enlarged area. This was done with a program which placed the numbers vertically up the screen of the CRT or the row, storing them on a theme (a memory location in the Image 100). The next row was annotated and its theme added to the previous theme. This was repeated until all the ground truths were annotated on each tree.

The next step was to train on a diseased tree to obtain its signature. Previous work has shown that all stages of disease ratings may be found in the diseased trees (2). By training on a diseased tree, we should alarm or show up all the trees with disease.

The data from channels 9 and 5 were ratioed by a program in the Image 100. This showed up the differences between the low reflectance in the visible divided into the high reflectance in the infrared. A 7-level density slice of levels 37-47 of the histogram was narrowed to 6 levels 37-45. There was no overlapping in channels 9 and 5, and the program used to make an alphanumerical printout of the enlarged area was called for. The ground truth ratings were printed with dots and the diseased pixels with an S (Fig. 1). When lines are drawn in the rows, the trees are boxed in. Where there are no S marks, the tree is either missing, a replant, or healthy. When the trees are all accounted for, a percentage was computed to the ground truth.

Fig. 1. Alphanumerical printout of channel 9:5 ratio. Visual ground truth ratings: 0 = healthy, 1 = slight, 2 = moderate, and 3 = severe. X = missing tree, Y = young tree, R = replant, and S = sick tree.

The data from the thermal channel 12 was also analyzed. Here an area of 100 trees was analyzed. The analyzer was trained on a No. 2 tree.

A 7-level density slice was used with a manual narrowing of the histogram or density levels made till no healthy trees were alarmed. With this level established, an alphanumerical printout was made using S for the diseased areas in the trees and no printout for the healthy or missing and replanted trees. When the lines were drawn to box in the trees, a percentage was computed vs. the ground truth (Fig. 2).

The alphanumerical printout showed 40 trees as diseased and 16 blank areas. Of the blank areas, the ground truth showed 5 replants, 5 No. 1 diseased trees, 1 missing tree, 1 No. 3 diseased tree, and 4 healthy trees. There were 48 trees in the 56 that agreed with the ground truth and 8 that did not. Although the printout agreed with only 4 of the 9 healthy trees, 2 of the downgraded healthy trees had lemon sprouts in them and 1 had a vine.

When the thermal band data, channel 12, 8 to 14 μ, was used with a manual density level slice in the Image 100, 87% of the alphanumerical printout agreed with the ground truth, Fig. 2.

A No. 2 diseased grade tree in row 6, tree 2, was used to train on. Here again, only the diseased tree was printed out using a S alarm and a blank area represented replacement trees, missing trees, or healthy trees. The ground truth was not annotated on the CRT in this 100-tree area. The ground truth showed 26 healthy trees, 37 No. 1’s, 20 No. 2’s, 6 No. 3’s, 6 replants, 5 missing, and 2 young trees.

By counting the areas that agreed with the ground truth of the 100-tree test area, 67 areas agreed that the trees are either diseased, missing, replants, young trees, or healthy trees. Of the 13 areas that did not agree with the ground truth, 5 areas that should have been blank and representing healthy trees had 1 or 2 S alarms representing diseased trees. Nine of the blank areas with no S alarm had ground truth 1’s in the areas. Of the 26 healthy trees, we had 21 blank areas agreeing with the ground truth. This would indicate that where we had the density limits set, there are some trees that are between 0’s and 1’s.

**Conclusion**

The analysis of digital multispectral data with the Image 100 gave a rapid mapping technique for trees under stress such as YTD. Knowing visual ground truth is not infallible and since some of the trees mapped had foot rot and probably other diseases than YTD, this technique may not be specific for YTD but probably indicates trees under the stress of disease.

With the density slicing programs used with the data from the ratio of channels 9:5 and the thermal channel 12, it is possible to agree with the ground truth from an ob server 86 to 87% of the time.

This technique is still in the experimental stage and this is the 1st result. In October of this year, we gathered data on a grove east of the Lake Alfred Research Center and had correlations from 13 to 84% with various experimental approaches to the data on the Image 100. To date, the lack of repeatability is a major area to overcome.

**Literature Cited**