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REMOTE SENSING APPLIED TO THE EVALUATION OF CROP FREEZE PROTECTION DEVICES

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ABSTRACT

Thermal images from an aircraft-mounted scanner are used to evaluate the effectiveness of crop freeze protection devices. Fuel oil heaters, wind machines and irrigation systems are evaluated from flights at an altitude of 450 m over an experimental citrus grove of 1.5 hectares.

INTRODUCTION

In the past it has been difficult to determine the effectiveness of various measures that are taken in order to prevent freeze damage to crops. This difficulty is caused in great part by the fact that temperature measurements made with conventional sensors such as thermocouples or thermisters are limited to a small number of discrete points. Usually, it has been through trial and error that methods were learned.

In recent years, however, infrared technology has advanced to the point where remote sensing in the 8-14μ "thermal" radiation region has become a common and reliable research tool. This provides a new perspective on evaluating freeze protection methods because measurements can be made from a scanning aircraft giving a spacially continuous overview of surface radiation patterns of a relatively large area. The full impact of the technology lies in the fact that under most conditions the magnitude of the emitted radiation is directly related to the surface (or crop) temperature (Sutherland and Bartholic, 1977). The data, when properly reduced give a temperature "picture" of an entire area as opposed to the more conventional ground measurements of a few discrete points. A major purpose of this paper is to report progress made by using the remote sensing technique.

Description of apparatus and test site

The test site is an experimental citrus grove located in Northern Florida near the University of Florida (~29.5°N, 53 m.a.s.l.). An aerial photograph of the grove is shown in Fig. 1. The trees in the northern 2/3 of the grove are approximately 4 m in height. Those in the southern 1/3 are shorter (3 m). Tree spacings are 3.05 m east-west (rows) and 4.88 m north-south.

Except for a few missing trees, the grove is homogeneous in the east-west direction. The grove is located on flat terrain of Kanapaha Fine Sand.

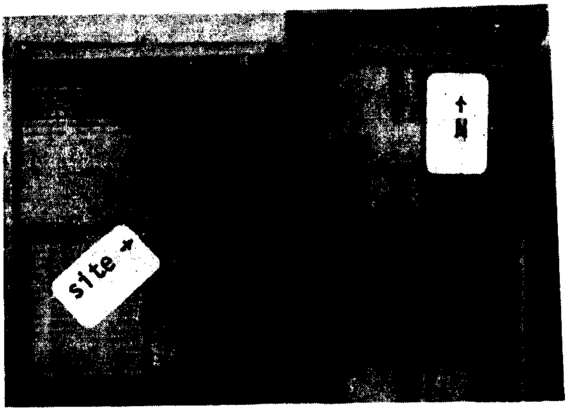

Figure 1. Aerial photograph of the test site.

A computerized data acquisition facility for ground truth measurements is located near the southwest corner. The grove is equipped with two heater types, Spots and Scheu on alternate rows spaced at every other tree along rows. The undertree irrigation sprinkler heads are in every row, centered in the row and spaced at every other tree. The irrigation pump is a 20 Kw electric motor and pumps well water (21°C) from a depth of approximately 30 m. The pump valve was adjusted to give a deposition rate at the sprinkler heads of 0.2 cm min^{-1}. The wind machine is 10 m high with a single propeller 4.7 m in length, is driven by a gasoline engine and rotates about a vertical axis once every 5 min.

The overall spacial resolution of the aircraft scanner is approximately 1.25 m^2 which is sufficient to resolve individual trees. The data which is recorded on magnetic tape as an analog signal aboard the aircraft was later digitized at a rate which maintained this resolution. In this paper the term pixel will be applied to this area. A more detailed description of the aircraft and scanner can be found elesewhere (Sutherland and Bartholic, 1975). A linear approximation was used to convert the scanner signal to surface temperature and emissivities are approximated as unity. Errors due to these approximations for the scanner bandpass of 8-14μ are small (Sutherland, et. al., 1978)

Results

Fig. 2 shows a typical thermal image of the test site which was taken during a time when the grove was in the natural (unprotected) condition. In Fig. 2, lighter areas are warmer and darker areas the colder. The entire range of the data is -8.9 to +0.56°C. The darker (colder) rows in the grove are the tree tops and the lighter (warmer) rows are bare soil.

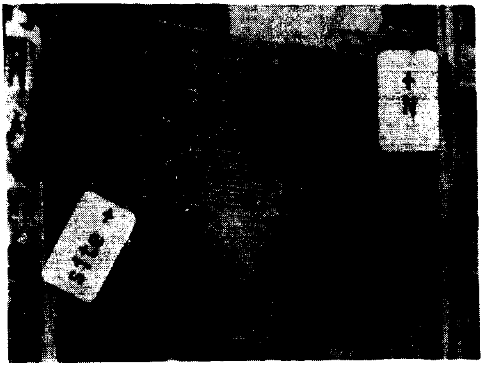

Figure 2. Typical thermal image of the test site taken when the grove was in the unprotected condition.

The digitized data used to produce the image of Fig. 2 was further analyzed by sectoring off only the area containing the grove and calculating the number of pixels (16000 total) found in the scene between various temperature intervals (i.e. histograms).

For evaluation of the wind machine the entire unprotected grove was considered the control then the data from a previous flight when the wind machine was operating is compared. For the heaters and irrigation the west half of the grove was considered control while the east half was first irrigated then heated.

All of the flights reported here were made on the night of 22-23 Feb. 1978. This was a calm night with no detectable wind. The experiments were started near midnight after most cooling had occured. Flights were then made approximately every two hours during which time nocturnal cooling was occuring at a nearly steady rate of 0.15°C/hour.

The resultant histograms of the thermal images are shown in Fig. 3. The mean temperatures of the distributions are marked along the x axis.

The results of Fig. 3a and 3b show the overall effectiveness of the wind machine, based upon the mean temperature of the grove to be 1.06°C. The broader distribution for the wind protected grove is indicative of the fact that the amount of protection provided by the wind is a function of distance from the machine which is located near the southwest corner of the grove. This was borne out in the accompanying thermal images (not shown).

The results of Fig. 3c and 3d show the overall effectiveness of the undertree irrigation, based upon mean temperatures only, to be 2.1°C. This mean, however, could be somewhat misleading since it is influenced by temperatures of the irrigation water itself, which was pumped in at elevated temperature. This is apparent from the bimodal distribution of Fig. 3d where the second peak at a higher temperature is certainly due to this fact. Perhaps a more accurate assessment of the effectiveness of the irrigation technique is the low temperature cut-off which by subtracting the lower thresholds gives an effectiveness of 0.78°C.

The results of Fig. 3e and 3f show the effectiveness of the heaters to be 1.5°C based upon means. This is again somewhat misleading for the same reason as before since some of the higher temperatures are the heaters themselves. By subtracting the lower thresholds, however, the effectiveness of the heaters is approximately 0.63°C, about the same as the irrigation technique. This latter observation is somewhat complicated by the fact that it was necessary to operate the wind machine during the heater experiment in order to protect the control portion of the grove from killing freeze damage. Perhaps a better direct comparison between irrigation and heating is to use the result of Fig. 3c as control for both. Viewed this way, the effectiveness of each is about the same.

Conclusions

The technique of remote sensing has been shown to be useful in evaluating freeze protection methods. Although more data is desired it can be concluded from the results shown that the technique of undertree irrigation competes effectively with that of heating. The economic significance of this latter conclusion lies in the fact that the cost of heating is about $20 per acre per hour while undertree irrigation is $.75 per acre per hour.

References

Sutherland, R. A. and J. F. Bartholic: 1974, "Aircraft-Mounted Thermal Scanner to Determine Grove Temperatures During Freeze Conditions," Proceedings of the Florida State Horticultural Society. 87, 65-69.

Sutherland, R. A. and J. F. Bartholic: Significance of Vegetation in Interpreting Thermal Radiation from a Terrestrial Surface," Journal of Applied Meteorology. 16, 759-763.

Sutherland, R. A., J. F. Bartholic and J. F. Gerber: 1978, "Emissivity Correction for Interpreting Thermal Radiation from a Terrestrial Surface," Journal of Applied Meteorology. In review.

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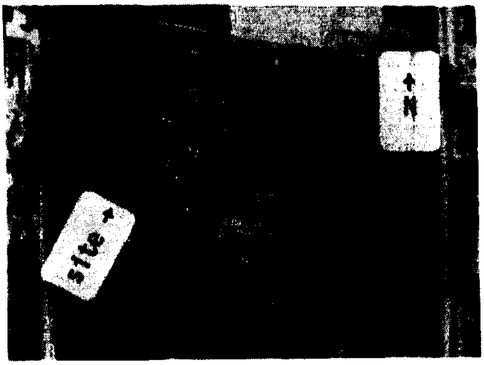

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