# THE USE OF SKYLAB DATA TO STUDY THE EARLY DETECTION OF INSECT INFESTATIONS AND DENSITY AND DISTRIBUTION OF HOST PLANTS

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ABSTRACT

A study of the detection of insect infestations and the density and distribution of host plants was undertaken using Skylab data, aerial photography and ground truth simultaneously. Additional ground truth and aerial photography was acquired between Skylab passes.

For the evaluation of S-190B data, two 100 square-mile areas within the task site were selected. Area 1, of high density citrus, was located northwest of Mission, Texas. Area 2, 20 miles north of Weslaco, Texas, contained different varieties of citrus, winter vegetables, sugarcane, irrigated pastures and brush-covered land. Skylab S-190A data was also evaluated for similar information over the entire Lower Rio Grande Valley and adjacent areas of Mexico.

Aerial photographs were obtained with an aerial camera having a 304.8 mm focal length lens and a 228.6 x 228.6 mm format with false color infrared, 2443 film and with a multispectral camera using aerial black and white infrared film, type 2424.

S-190A data was recorded May 30, 1973 on 70 mm film. The highest resolution was obtained with the conventional color (SO-356) and black and white film (SO-022). A color composite picture of S-190A data using a multispectral viewer in the red, blue, green and infrared channels showed patterns of vegetation on both sides of the Rio Grande River clearly delineating the possible avenues of entry of pest insects from Mexico into the United States or from the United States into Mexico. The maximum resolution obtained with this film was approximately 150 feet.

Earth Terrain Camera imagery (S-190B) was received during the month of April, 1974. The highest resolution of approximately 27 feet was obtained with conventional color (SO-242) and black and white (EK-3414) film. The resolution of the color infrared film (SO-131) was approximately 50 feet. The conventional color film was exposed on December 5, 1973. The color infrared film was exposed on January 28, 1974.

On December 21, 1973 freezing conditions caused severe damage in some crops and eliminated some of the vegetation that normally would have been visible on the color infrared film. The identification of crops being grown at this time was obtained through simultaneous comparison of the conventional color and color IR film. With color IR film, citrus appears as a very dark red color separating it from brush and sugarcane which contained no visible red color due to damage from freezing temperatures. With the conventional color film which was exposed before the freeze, sugarcane could easily be separated from brush and citrus, but in some instances citrus could not be readily separated from brush except where the geometric shape and pattern of the field was a determining factor.

Other vegetation that could be identified with Skylab color IR film was winter vegetables, alfalfa, irrigated pastures, unimproved pastures and different densities of citrus plantings. Insect infestations in citrus were at low levels during the Skylab pass. However, with the resolution capability of color infrared film and its sensitivity to infrared reflectance, it is evident that heavy infestations of

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honeydew producing insects, such as Coccus hesperidum L., Planococcus citri (Risso) or Aleurocanthus woglumi Ashby, in citrus would have been detectable. Dark soil patterns within a grove could adversely affect the detection of insect infestations since the overall reflectance would be reduced and the contrast between dark areas would be less detectable.

## INTRODUCTION

Aerial photography has been demonstrated to be an effective tool in research and the practical applications of agriculture. Hart and Myers (1968) using aerial color infrared film were able to detect light to heavy infestations of brown soft scale, Coccus hesperidum L. on citrus. This work was accomplished with color infrared film at a photographic scale of 1:10,000. In 1973 Hart et al. demonstrated that the same technique could be used to detect citrus blackfly, Aleurocanthus woglumi Ashby, infestations in citrus groves. An aerial photographic survey method was developed from these studies that provided a rapid and effective method of detecting these problem areas, thus significantly reducing survey time and expense for this serious citrus pest.

Hart et al., in 1971, were able to identify citrus mealybug infestations using aerial color infrared film. The identification of brown soft scale, citrus mealybug and citrus blackfly infestations on citrus foliage is accomplished by detecting the sooty-mold fungus, Capnodium citri Berk, which grows on honeydew, an end product of metabolism of these insects. The patterns in which the sooty-mold develops on the foliage provides an effective means for specifically identifying infestations of each of these three pests of citrus.

Aerial photography, using color infrared film provided detection of three insects, one mite and three diseases on pecans and peaches in South Georgia (J. A. Payne, et al. 1971).

Ants can also be easily detected with aerial photography as a result of their characteristic mounds. In 1971 studies by Hart demonstrated that mounds of imported fire ants Solenopsis invicta (Buren) could be detected with aerial infrared color photography and that an inexpensive technique for aerial surveys could be established. Later studies by Green et al. (1975) provided in depth information on precise altitude and effectiveness of this survey technique for imported fire ants. Other ant mounds that can be detected are those produced by the harvester ant, Pogonomyrmex barbatus (F. Smith) and Texas leaf cutting ant, Atta texana (Buckley).

These studies demonstrated that insect infestations of crop plants and pastures that are detectable by aerial photography can be divided into four categories according to the type of damage they cause: (1) honeydew producers from which sooty-mold deposits develop on foliage, (2) those that distort geometric patterns of plants, (3) those that cause color changes in foliage and (4) those that produce identifiable structures (i.e. ant mounds).

The ability to rapidly identify the density and distribution of host plants of various pests can provide a major input into large scale eradication programs of established pests, containment or control programs of newly introduced pests, and in studies of population dynamics. Usually the most damaging situation that can occur with an insect pest is the introduction of a destructive species to a new area. This results because the pest insect usually arrives without any of its natural enemies which causes the pest population to increase very rapidly, inflict severe damage to an area, and remain destructive for prolonged periods. A thorough knowledge of all vegetation in areas that are potential hosts of new introductions of insect pests is vital for the prevention, eradication, containment, or control of these pests. Adequate ground surveys of many of these areas are frequently impractical because they are extremely time consuming, costly, and in most cases not very efficient, since many of the areas of concern are inaccessible. In view of this, Hart and associates in 1973 developed techniques for determining the density and distribution of host plants of various pests using aerial photography. Since aerial photography using color infrared film proved successful in the above studies, the use of Skylab data was investigated to determine the feasibility of detecting insect infestations and avenues of entry of pests into previously uninfested areas.

Methods and Materials:

A task site was established in the Lower Rio Grande Valley from which data was gathered using ground surveys, aerial photographs and Skylab data. Within the task site, two 100 square-mile areas were selected in which data gathering was concentrated. Area 1, which contained a high density of citrus was located northwest of Mission, Texas. Area 2, located 20 miles north of Weslaco, Texas contained several varieties of citrus, winter vegetables, sugarcane, irrigated pastures, fallow land and brush-covered land. In addition to these two large plots, three one square-mile plots were selected at random from within the task site in which highly concentrated data gathering was undertaken.

The data gathered by ground survey was concerned with insect infestations, planting densities, variety differences, soil patterns, crop inventories, acreage measurements and location of canals, roadways, drain ditches, lakes and low areas.

Aerial photographic data was acquired with an aerial camera which had a 304.8 mm focal length lens and a 228.6 x 228.6 mm format. Film used in the camera was color infrared film (2443) with a filter pack containing a Wratten 12 and 40 cc blue filter. Aerial photographs were taken at altitudes of 609, 1524 and 3048 meters, above ground level providing a scale of 1:2000, 1:5000 and 1:10,000, respectively. A single engine aircraft containing a 450 mm diameter camera port on the floor to facilitate vertical photography was used for a photographic platform. The film was processed at the Citrus Insects Laboratory, Weslaco, Texas. Photography obtained was viewed on light tables with or without magnification and compared with ground truth and Skylab data.

A multispectral camera with aerial black and white infrared film (2424) was also used for gathering aerial data. This camera contains four 150 mm focal length lenses. Each frame recorded four images of the same area simultaneously, each with a format of 57 mm x 103 mm. One image was photographed in the green wavelength band, one in the blue band and one in the near infrared to 900 nanometers. This data was viewed with a multispectral viewer which can be used to combine all four channels, producing a color composite, or to view any of the wavelength bands separately or in combination.

Skylab data was received from S-190A and S-190B cameras. The S-190A camera, a multispectral photographic camera system consists of an array of six 70 mm cameras, each equipped with f/2.8 lenses having a focal length of 152.4 mm which provided approximately 25,600 sq. kilometers of ground cover per frame. Each camera was designated as a station and was equipped with different film and filter combinations. Camera stations one and two contained black and white infrared film (2424) and a

CC[1/] filter (0.7-0.8 micrometer) and a DD[1/] filter (0.8-0.9 micrometer), respectively. Station three contained EE[1/] filter (0.5-0.88) and color infrared film (2443). Station four was equipped with a FF[1/] filter (0.4-0.7 micrometer) and hi-resolution color film (SO-356). Stations five and six were equipped with black and white film (SO-022) and contained a BB[1/] filter (0.6-0.7 micrometer) and an AA[1/] (0.5-0.6 micrometer), respectively.

The Earth Terrain Camera, S-190B, utilized 127 mm film and was equipped with an F/4 lens with a focal length of 457.2 mm providing ground coverage of approximately 11,881 sq. kilometers. Earth Terrain Camera imagery was exposed Dec. 5, 1973 and Jan. 28, 1974 and was received April 1974. This imagery consisted of conventional color film (SO-242) and high-resolution color infrared film (SO-131).

S-190A data was received during the month of August, 1973. This film was exposed May 30, 1973 and covered a major portion of the task site. A large area south of the task site, in Mexico, was also included in the coverage. The S-190A data was evaluated by comparing it visually with aerial photography and ground data. The black and white multispectral Skylab photography was observed in the multispectral viewer, producing a color composite which was compared with the other data.

When the Skylab 190B film was received, enlarged 35 mm transparencies were made from the original scale of 1:1,000,000 to a scale of 1:63,000. This was then projected to provide a scale of 1:10,000. Using this scale, two agricultural photointerpreters analyzed all items in each test site on each film type. After analyzing each film independently a comparison study was made of the color IR and conventional color films. Using this technique color, density, and physical features provided information necessary for correct identification of the composition of the agricultural scene. The interpretation was aided by the fact that the conventional color film was exposed before a freeze and the color infrared was exposed after the freeze. Fig. 1 demonstrates one of the test sites and the sources from which the data was acquired.

In order to determine the accuracy of the interpretation of various features within the areas, a study was conducted using S-190B color infrared and conventional color film. Within the 100 square mile test area, three one square mile test sites were randomly selected. Ground surveys were conducted to obtain ground truth which was used as a basis for determining accuracy. Aerial surveys using color infrared photography of the three sites were also conducted. All of this data was obtained plus or minus 24 hours of the Skylab pass over the task site.

The Skylab 190B was analyzed to identify various crops in the test site with both color infrared and conventional color film and to evaluate the influence of freezing temperatures and other environmental factors on sugarcane, cabbage, alfalfa and soil reflectance patterns. Since it was anticipated that the planting density of citrus trees would effect the gross reflectance from the crop and thus influence the accuracy of detection of problems, a study was also made on the effect of tree spacing on reflectance.

In order to demonstrate the ability to quantify differences between brushland, sugarcane and citrus, a density study of the various areas was conducted on conventional color S-190B film. Using a 1:63,000 scale transparency, six randomly selected density readings on each film type were made with a transmission densitometer that has a 1-mm aperture.

[1/] AA, BB, CC, DD, EE and FF are NASA designations for filters providing the band widths indicated.

Since color infrared photographic data was obtained using different types of color infrared film and exposed from different altitudes above the subject being photographed, a comparison test of resolution was undertaken to determine the effects of the different types of film and altitudes on resolution.

The test plot used for this comparison was located in area No. 2 and contained 640 acres. The plot contained crops, fallow land, roads and canals from which accurate measurements on the ground were taken.

Skylab photography, S-190A and S-190B was enlarged photographically to its maximum useable scale which was 1:200,000 for S-190A and 1:30,000 for S-190B. S-190A used EK-2443 color infrared film and S-190B used SO-131, a high resolution color infrared film.

Aerial photography with color infrared film (2443) exposed at a scale of 1:10,000 over the test plot was adjusted to a scale of 1:20,000 to compensate for the smaller adjusted scale of Skylab data and thus make the comparisons more equitable.

Objects measured on the ground were located on the aerial and Skylab data and comparative measurements were taken from each photograph. Only areas of high contrast were used so that the maximum resolution could be obtained.

Results:

The S-190A data provided significant information on areas of vegetation on both sides of the Rio Grande River. On the conventional color film the physical features of the area such as drainage patterns, water courses and some soil characteristics are readily apparent (Fig. 2a). With the color infrared film (Fig. 2b) the patterns of vegetation which appear as shades of red are very clear. Despite reduced resolution much more information about the distribution of vegetation on both sides of the border is evident with the color infrared film. This photography clearly defines the possible avenues of entry of pest insects from Mexico into the United States and the United States into Mexico because of potential host distribution. The multispectral color infrared composite picture (Fig. 2c) which included the spectral region between 0.5 to 0.9 micrometers, intensified the signature of vegetated areas making it possible to see more vegetation and more accurately pinpoint possible avenues of entry of pest insects. Areas of little vegetation and subsequently less stress, are also clearly evident.

Following the freeze of December 21, 1973 sugarcane demonstrated a major change in reflectance but pastures, and annual crops showed little change. This was due to the absence of chlorophyl in the sugarcane brought about by freeze injury. In Fig. 3, the two film types (color IR and conventional color) each exhibited advantages for some problems, but when the films were viewed simultaneously, comparing each item, the accuracy of identification increased markedly. This is due in varying degrees to the two film types, to the differences in reflectance characteristics that occurred after a freeze, and to the combination of both.

With the color infrared film, annual crops, fallow land, variations in soil color and low areas were correctly identified 100% of the time. Citrus was identified with

93% accuracy. With conventional color film the accuracy of identifications of citrus dropped to 80% but when both films were compared, citrus was identified correctly in every instance.

When comparing the 2 film types the only items identified with less than 100% accuracy, as indicated in Fig. 3, were brush, homesites, missing plants within crops, and canals.

The best resolution obtained from S-190B data was 8.2 meters at areas of high contrast with conventional color film (SO-242). Resolution of color infrared film (SO-131) was 15.2 meters at areas of high contrast. In Test Area 1, which contained one hundred square miles, it was determined from ground surveys that citrus planting densities varied from 225 trees per hectare to 313 trees per hectare in several groves. This planting density was also very apparent with aerial photography using color infrared film (2443) at a scale of 1:10,000. When viewing S-190B color infrared film, the higher density planting areas appeared darker in color than the lower density plantings (Fig. 4). This was most obvious when citrus was planted on highly reflective soils.

At the time of year S-190B film was exposed, a large portion of the cultivated land in the task site was fallow land. Vegetation present at that time of the year was limited to citrus, sugarcane, winter vegetables, irrigated pastures and cover crops. Uncultivated land contained sparse vegetation of native grasses, shrubs and trees.

With S-190B color infrared film (Fig. 5a) citrus appeared as a very deep red color, separating it from brush and sugarcane which contained little or no visible red color at this time of year. On Dec. 21, 1973 the sugarcane had been subjected to freezing temperatures shortly before it was photographed leaving it devoid of any infrared reflecting chlorophyl. Brush at this time of year does not normally show up well on color infrared film due to the reduced chlorophyl content. With normal color S-190B data (Fig. 5b) sugarcane which had not been damaged by adverse temperatures when this film was exposed could easily be separated from brush and citrus, but citrus in some instances appeared very similar to brush. In some cases the geometric shape of the field could be used as a determining factor in separating the two. Brush covered areas in the test site are usually large and have irregular patterns whereas most citrus groves in the valley are smaller and more uniform in color and texture throughout.

A field of sugarcane planted on the east side of a large body of water, Delta Lake, demonstrated the moderating effect of large bodies of water on temperature extremes. The sugarcane next to the lake, which was uninjured by freezing temperatures, appeared red on S-190B color infrared film while cane at a greater distance from the lake, appeared black, demonstrating the effect of freeze injury (Fig. 6a). This was the only field that was observed to be undamaged on S-190B color infrared film following the December 21, 1974 freeze.

The most abundant winter vegetable growing at the time S-190B color infrared and conventional color film was exposed was cabbage. With CIR film cabbage appeared bright red which was easily distinguished from the dark red signature of citrus (Fig. 6b). Harvested cabbage fields appeared pink. On the S-190B conventional color transparencies mature cabbage appeared green and after harvest was light green.

Alfalfa appeared as a much brighter red color than all other vegetation growing at the time S-190B color infrared film was exposed. Alfalfa foliage usually provides complete coverage of the soil thus preventing any interference with overall IR reflectance characteristics. An alfalfa field within the first area of the task site had suffered considerable wind damage leaving areas within the field void of vegetation. This was very apparent when viewing S-190B color infrared film (Fig. 6c) because of the bright red reflectance of the undamaged alfalfa compared to the white reflectance of dry soil where the damage occurred.

Problems in sugarcane fields such as chlorotic areas are hard to detect from the ground due to dense planting. With aerial photography, these areas can be easily seen. Chlorotic areas were detected in a sugarcane field when viewing S-190B normal color film (Fig. 6d) The smallest area that could be seen was 9 meters in diameter when magnified to a scale of 1:125,000. Figure 6d is an example of a sugarcane field containing several chlorotic spots. Approximately ten acres of the 40 acre field had chlorotic damage.

Soil reflectance patterns were demonstrated to have an adverse effect on the identification of some citrus problems with data acquired from aircraft and Skylab. In the task site there were two basic patterns of soil reflectance that were consistently evident. These soils appeared either white or of varying intensities of blue. White soils are due to the soil being dry or very sandy. Dark soils in the test site were due to the high moisture content of the soils or deposits of silt that accumulate in various locations. S-190B color infrared data (Fig. 6f) demonstrates fallow land containing light soil with a dark soil pattern running through it. In a citrus grove, where the reflectance of soil blends with the reflectance of foliage, soil patterns can cause difficulty in interpretation of the data from Skylab (Fig. 6e). Dark soil patterns in a citrus grove may appear similar to insect infestations or high density of plantings.

The average diffuse transmission density (6 readings each) for brushland, sugarcane and citrus was 13.1%, 21.0% and 9.8%, respectively (Fig. 7). While there was some overlap in the readings for brushland and citrus, it is evident that the averages are significantly different and that brushland and citrus can be separated with this technique.

Using the ground data and the photographic data, resolutions were established. Aerial color infrared film provided a resolution of 46 cm., S-190A 45.7 meters and S-190B 15.2 meters (Fig. 8).

Conclusions:

Satellite data such as that obtained from Skylab S-190B offers promise for detection of some insect pests and the distribution of host plants of various insect pests. The practical applications of this technique will be dependent on maximum resolution and rapid turn around time in receipt of the data.

With comparative observations of film types and seasonal influences on reflectance characteristics, many crop varieties can be identified with Skylab S-190B data.

Vegetative patterns in border areas can be detected with Skylab S-190A and S-190B data. This information can be useful in detecting avenues of entry of pest species and areas of stress that require greater vigilance in stopping the spread of destructive species.

The influence of some environmental factors on crops that may be confused with pest injury, or related factors, can be detected and identified with Skylab S-190B data.

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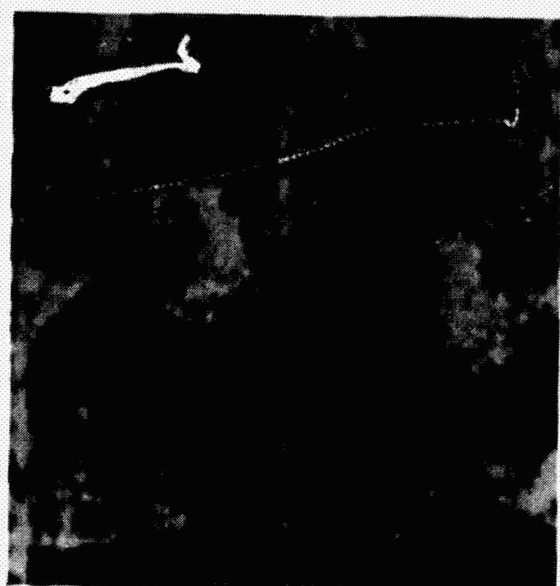
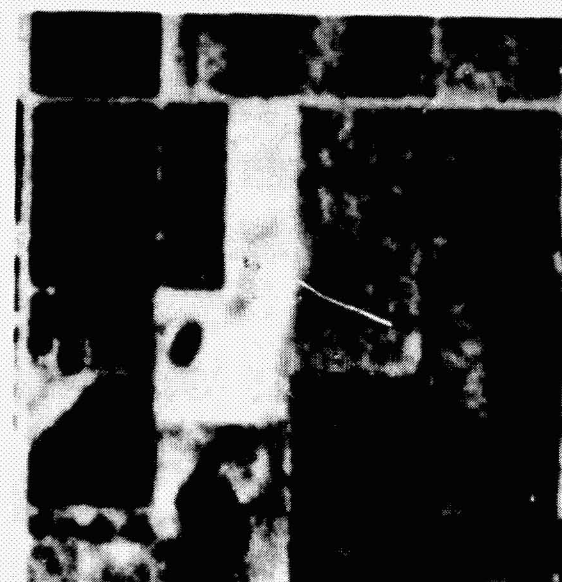
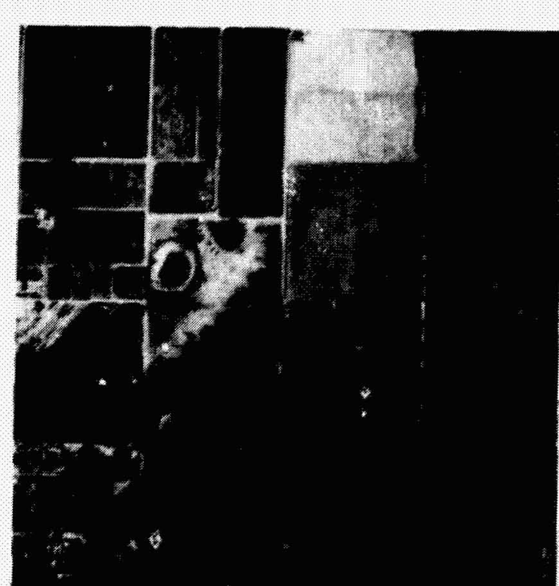


(a) Color Infrared (S-190B)

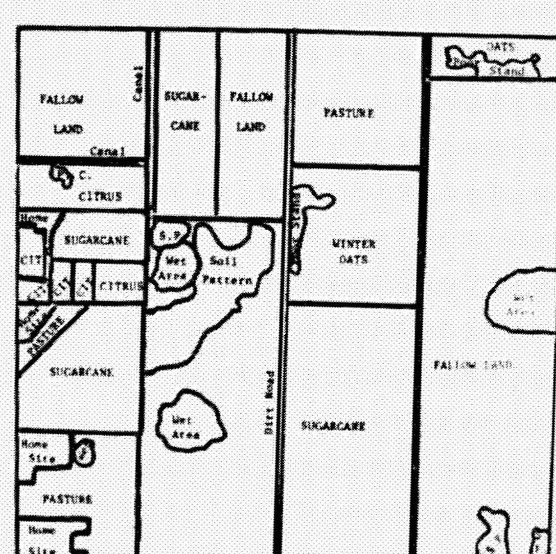


(b) Conventional Color (S-190B)



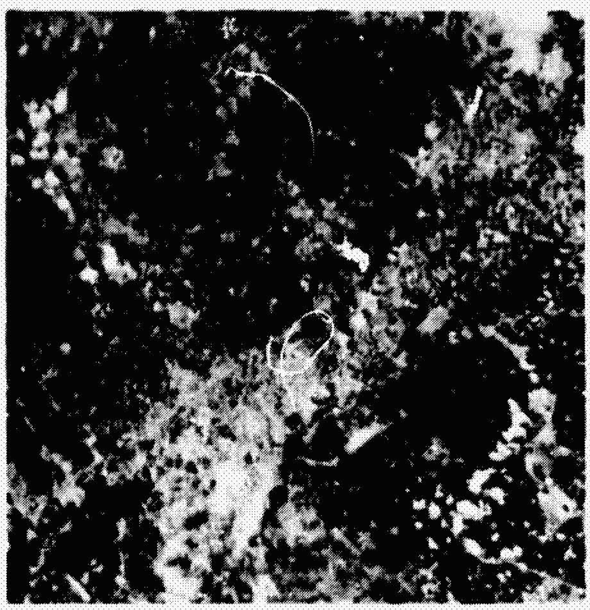


(c) Color Infrared fram Aircraft

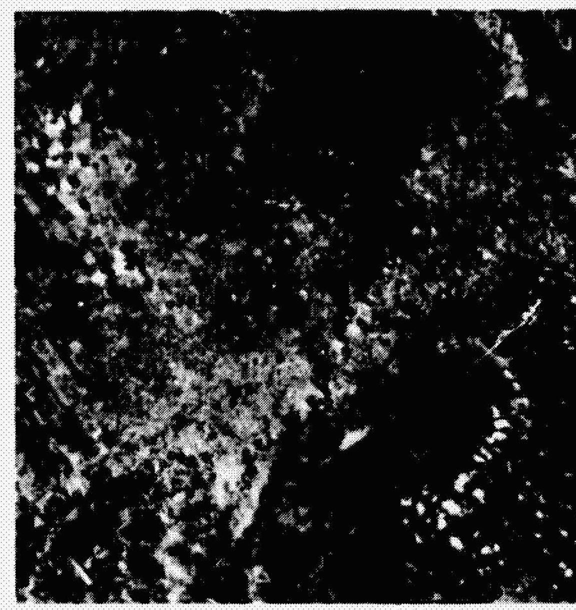



(d) Ground Truth Map

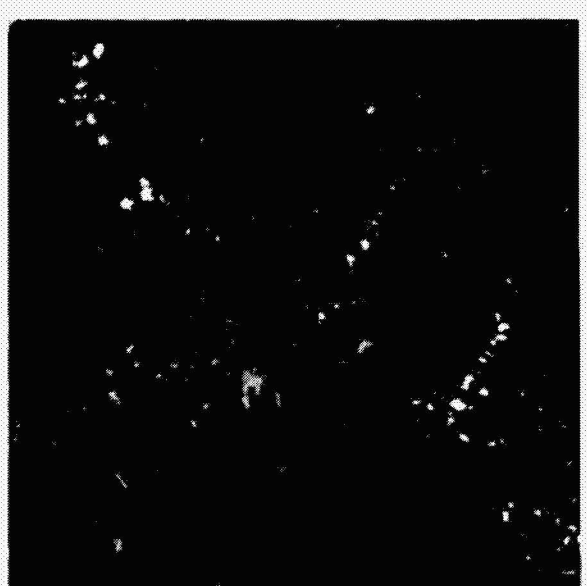
Figure 1 Comparison of data sources indicated in 1 square mile test site.



(a) Coventional Color



(b) Color Infrared

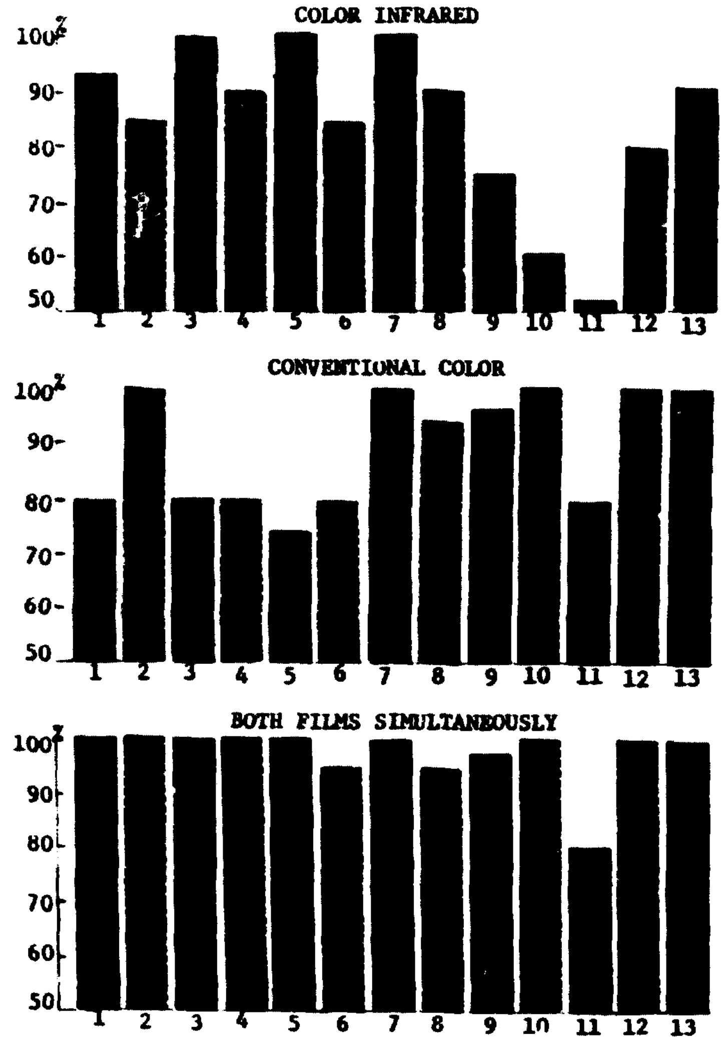


(c) Multispectral Color Infrared Composite

Figure 2 A comparison of S-190A conventional color, color infrared and black and white film. Black and white film was combined in a multispectral viewer to produce the color composite.

PHOTO INTERPRETATION ACCURACY FOR SKYLAB 190B DATA

Figure 3.




1. CITRUS (2 YRS. AND OLDER)
2. SUGARCANE
3. ANNUAL CROPS
4. PASTURES
5. FALLOW LAND
6. BRUSH
7. SOIL PATTERNS AND LOW AREAS
8. HOMESITES
9. MISSING PLANTS WITHIN CROPS
10. DRAINAGE DITCHES
11. CANALS
12. UNIMPROVED ROADS
13. HIGHWAYS

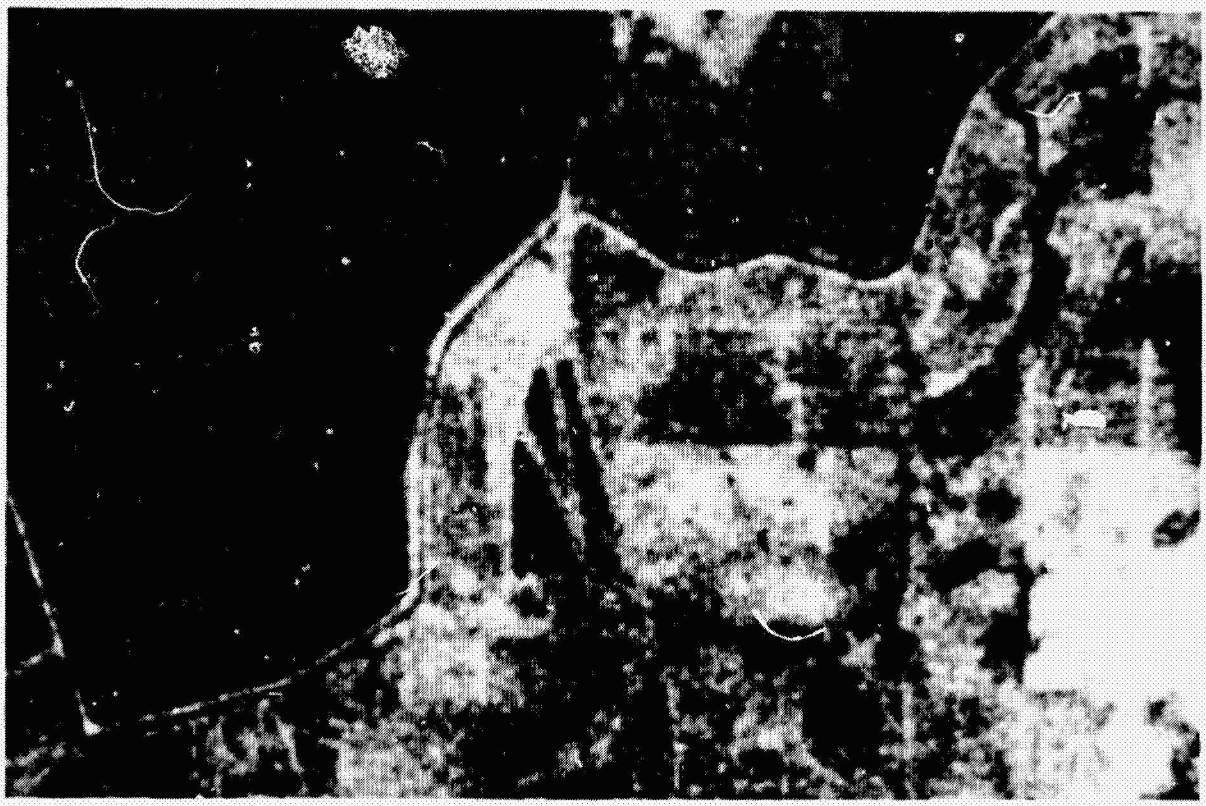


Figure 4. High and Low Density Citrus Plantings.

(a) Color Infrared

(b) Conventional Color

Figure 5. S-190B color and color infrared photographs of the 100 square mile Test Area.

(a) Sugarcane Protected from Freeze
Color Infrared

(b) Cabbage Partially Harvested
Color Infrared

(c) Wind Damage to Alfalfa
Color Infrared

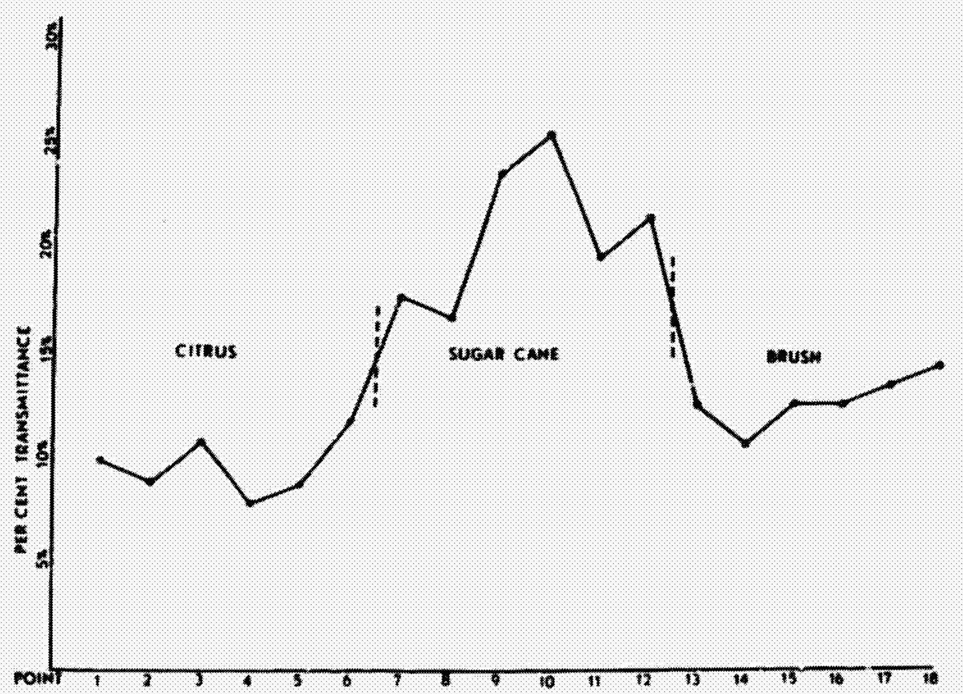
(d) Chlorotic Area in Sugarcane
Conventional Color

(e) Soil Patterns in Citrus Grove
Color Infrared

(f) Soil Patterns on Fallow Land
Color Infrared

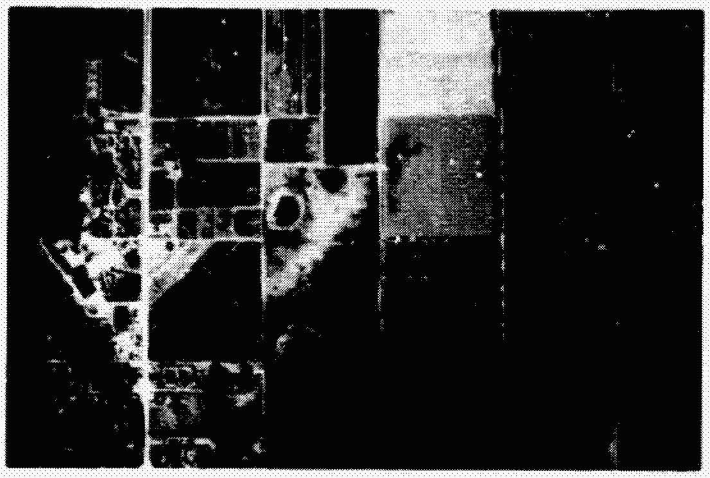
Figure 6. Selected agricultural items of interest in the 100 square mile test area.

(a) Enlarged S-190B photograph showing citrus, sugarcane, and brush




(b) Densitometer reading

Figure 7. Diffuse transmission density of citrus, sugarcane, and brush.



(a) Color Infrared Aerial Photograph

(b) S-190B Color Infrared

(c) S-190A Color Infrared

Figure 8. Comparison of Aerial, S-190B, and S-190A photography in 100 square mile test area.