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APPLICATION OF ERTS-1 IMAGERY & UNDERFLIGHT PHOTOGRAPHY IN THE DETECTION AND MONITORING OF FOREST INSECT INFESTATIONS IN THE SIERRA NEVADA MOUNTAINS OF CALIFORNIA

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ABSTRACT

Preliminary analysis of ERTS-1 imagery in a rugged mountain area in the Sierra Nevada Mountains of California indicates some promising possibilities of detecting two types of insect infestations as our primary objective and secondary detecting and mapping other features such as timber or untimbered areas; timber stand density; principal stream courses, mountain meadows, lakes, massive rock outcrop and domes, riparian vegetation, grazing land and possible glaciers. We have used and found exceedingly useful, NASA underflight RC-10 imagery.

1. INTRODUCTION

In the general field of pest management early detection and monitoring of insect outbreaks are of paramount importance in the protection and management of our natural resources. If an insect pest reaches outbreak proportions before it is detected, supression measures become very costly, and even if effective, are applied only after the host crop has been severely damaged. This is particularly true of forest insect outbreaks in remote areas.

The longtime, overall objective of our study was to develop space data acquisition methodology which would permit rapid, accurate and comprehensive detection and monitoring of insect infestations and other causes of physiological stress and morbidity in vegetative ecosystems, through the use of ERTS-1 imagery alone, and when supplemented by underflight photography. It was hoped that this methodology, when fully developed, would eliminate the present need for expensive, patchwork aerial and ground surveys and would provide a continuously up-dated basis for operational programs of control and salvage, and would permit frequent evaluation of economic and ecological impact of existing and impending infestations as a basis for determining broad research and control strategies.

In addition to ERTS-1 imagery we also had available, through contract with Earth Satellite Corporation, color infrared, for the total test sites at a scale of 1/18,500, and sample coverage of about 10 percent of the area in color and color infrared at a scale of 1/5,000 in

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9" x 9" transparencies, as well as U-2 support covering the entire target area. Earth Satellite Corporation also subcontracted on some of the photo interpretation and multistage sampling technique.

2. THE TEST SITE

The test site selected was in the Sierra Nevada Mountains of California where we had long standing research evidence of the existence of heavy damage by the mountain pine beetle, Dendroctnus ponderosa, (Fig. 1) and reasonable expectations of an outbreak of the lodgepole needle miner, Recurvaria miller, (Fig. 2), developing during the course of the study.

The area is centered in the Yosemite National Park and represents some of the most rugged mountainous terrain in the West; with high elevations ranging from about 7,500 to more than 12,000 feet, and subalpine coniferous forests in which lodgepole, the host species, was the dominant tree species. (Fig. 2).

Because of the wide range in sizes of the infested timber blocks, it should offer opportunity to determine the smallest area consistently identifiable from, (a) ERTS-1 imagery, (b) from conventional aerial photography, and (c) from a combination of both.

3. PEST CHARACTERISTICS

The two dominant pest species were the lodgepole needle miner and the mountain pine beetle. The lodgepole needle miner is one of the most destructive defoliators of some of California's most scenic mountain forests, and its feeding causes the foliage to turn brown. The caterpillars of this inconspicuous moth feed within the pine needles, and have a two-year life cycle, with maximum damage and discoloration of the needles occurring at the end of the second year. In this study, maximum brown discoloration is expected to be late spring, 1973.

The mountain pine beetle is one of the most destructive bark beetles in the West, particularly in lodgepole pine. The trees are killed by the feeding of the larvae in the cambial area, causing the foliage to change from green to red. The second year after death, the bark beetle trees change to a gray color with most of the foliage gone.

4. PROCEDURE PRIOR TO THE RECEIPT OF ERTS-1 IMAGERY

Aerial photos in color and color infrared were obtained, processed and interpreted at scales of 1/18,500 for the whole area and at 1/5,000 for sample areas representing differing degrees of damage. Ground truth was then obtained by careful analysis and classification of each tree as to its condition, on a series of four-acre plots selected at random.

Analysis of these data permitted the target area to be classified into damage units as light, medium, and heavy for both needle miner and

FIGURE 1

An example of almost total kill of mature lodgepole pine (Ghost Forest) in Yosemite National Park as a result of a combination of needle miner and the mountain pine beetle. This would represent our designated heavy damaged area.

FIGURE 2

An example of heavy damage to lodgepole pine from the needle miner in an earlier outbreak in the Tenaya Gap Area. Light colored trees in the foreground damaged; darker ones in the background are non-host mountain hemlock. Note the rugged topography and foreground which is almost solid rock.

the bark beetle. Due to an early snow storm, only about 90 percent of the ground truth was collected and analyzed prior to the receipt of the ERTS-1 imagery.

5. INTERPRETATION OF U-2 SUPPORT

We had U-2 photo coverage in 70mm black and white, April, May and June, 1972, but found this of little use for detecting insect damage. We received our first RC-10 aerochrome infrared photos on December 3, which were flown on July 27, 1972, and made a comparison of these with our own 1/18,500. We found that using the original 1/120,000 scale we could detect many, but not all of the areas of heavy and medium damage. We found by enlarging the U-2 photos to approximately the same scale as our 1/18,500, that in this particular test area, we were able to detect all degrees of damage detectable on our original 1/18,500. The main contrast in this test was between a heavily damaged area and one with little or no damage. We need to run further tests with the enlarged U-2 under stereo to determine if we can identify individual trees, which is possible on our original 1/18,500 color infrared, and to explore other areas of different degrees of damage. We feel encouraged by these preliminary tests and are hopeful that the U-2 by itself will prove to be an important tool in forest insect detection and monitoring.

Our only criticism of the RC-10 was that the images were generally dark, and we failed to get good detail in deep canyons and shaded northern slopes. We would suggest in future U-2 support in mountainous country that the exposure be changed to compensate for the generally darker target areas.

We ran some tests on the same film strip in the Bay Area, and the exposure appeared to be extremely good. Our tentative conclusion is that black and white is of little value in detecting forest insect damage under the conditions of our test.

6. ERTS-1 IMAGERY INTERPRETATION

Because we were delayed in receiving our ERTS-1 color infrared transparencies until December and had difficulty getting enlarged prints of our target area, we have only partially analyzed our data. For this reason, our conclusions must be considered as tentative. We have had four men interpreting the imagery including: Dr. Thomas Koerber, from the Pacific Southwest Forest & Range Experiment Station; Dr. B. H. Wilford and Dr. R. C. Hall, from Natural Resources Management Corporation, and Stephen Daus, from Earth Satellite Corporation. The first three named are all experienced forest entomologists with considerable experience in interpretation of insect damaged areas from conventional aerial photos. Daus is a forestry graduate and an experienced photogrammetrist. We also had the close cooperation of Ralph S. Mac Farland, the Chief Photographer from the Pacific Southwest Forest & Range Experiment Station who aided greatly in image enhancement.

Interpretation was done partly in stereo in the original NASA positive transparencies, but we were unable to cover the whole area in stereo. We worked with enlarged color prints from these ranging in scale of one inch = 4.5 statute miles to one inch = 1.25 statute miles.

The concensus of all interpretors was that our scale of one inch = 1.25 statute miles was the best of the series, and we were able to identify three degrees of tree mortality, light, medium, and heavy (Fig. 3) with a reasonable degree of certainty. It should be pointed out, however, that this test represented only one time phase, September 16, 1972, with optimum cloud free conditions. We are scheduled for ERTS-1 imagery in late June and again in August. We expect little change in color rendition in our tree mortality areas, but do expect more contrast in our defoliated areas, as well as drastic changes in mountain meadows and grassy areas interspersed in the timber. At the time of our September imagery, our mountain meadows were light brown, and we expect these areas to be dark green by June.

Time did not permit the planned differentiations of defoliated areas where we are able to classify these into light, medium, and heavy damage.

We were able to differentiate the bark beetle damage areas principally on the basis of color differences. We have classified these colors as follows:

Imagery: ERTS-1 NASA Original Color Transparancy
September 16, 1972, Yosemite Frame

Classification	Color by Eye	From Munsell Book of Color
Light Mortality	Cherry-red	5R - 5-8
Heavy Mortality	Milk Chocolate Brown	10RP - 4-4
Mountain Meadows	Light Yellow	10YR - 8-8
Lakes	Dark Blue	10B - 2-4
Dome Shadows (resembling lakes)	Black	10B - 2-1

Imagery: Enlargement to scale 1" = 1.25 S.mi.

Heavy Mortality	Moldy-yellow	5YR - 6-4
Medium Mortality	Chocolate Brown	10R - 5-4
Light Mortality	Blood-red	5R - 4-8
Grassy Areas in Timber	Cherry-red	5R - 5-8

7. SIGNIFICANT RESULTS

In our preliminary tests, we are reasonably sure that we can do the following: differentiate areas of heavy damage from those with little or no damage in the lodgepole pine type; non-timbered vs timbered areas; lakes;

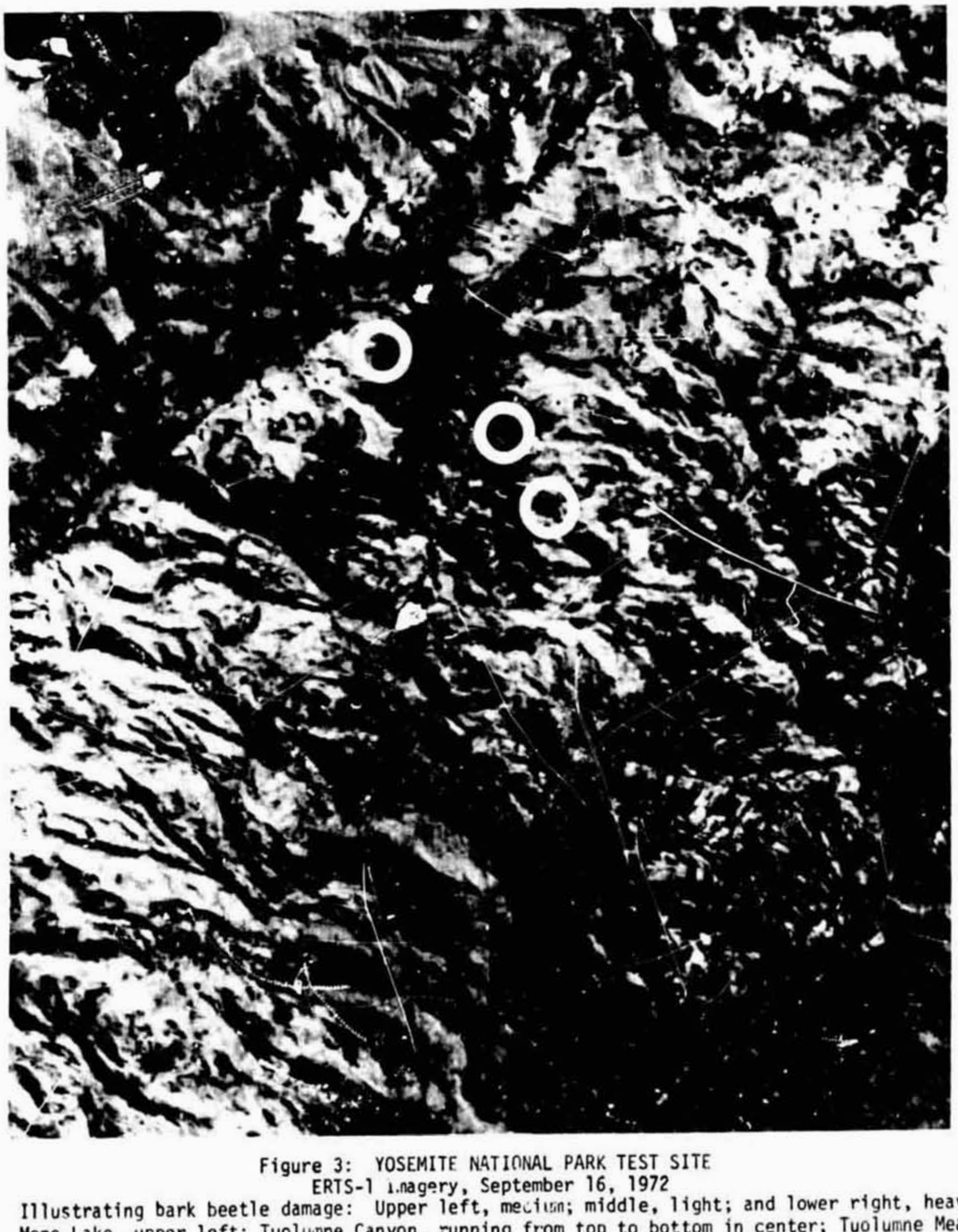

Figure 3: YOSEMITE NATIONAL PARK TEST SITE
ERTS-1 imagery, September 16, 1972
Illustrating bark beetle damage: Upper left, medium; middle, light; and lower right, heavy. Mono Lake, upper left; Tuolumne Canyon, running from top to bottom in center; Tuolumne Meadows, upper center.

Scale: 0 5 10 Statute Miles

rock domes and rock dome shadows, which closely resemble lakes; mountain meadows; pasture and agricultural land; and desert, from the ERTS-1, NASA prepared color transparencies.

We are more confidant of our work with the enlargements of the above imagery to a scale of 1" = 1.25 statute miles, where we believe that we can definitely differentiate between heavy, medium and light damage in a sample area selected where we knew these three conditions existed. U-2, RC-10 compares quite favorably with conventional infrared color photography except in deep canyons and shaded northern slopes.

8. COST BENEFIT ANALYSIS

We have done no significant work on this phase of the problem, but we hope to do so in the near future. We have been experimenting with an in-house system in cooperation with the Pacific Southwest Forest & Range Experiment Station; where we believe that we can speed up the enhancement of ERTS-1 imagery where it can be rapidly interpreted and screened for any suspected massive areas of damage. We will also attempt a comparison of cost with that of the conventional Regional Aerial Survey System.

9. CONCLUSIONS

As a result of our research to date, we can arrive at the following conclusions: (1) If we develop a system which can be expected to replace the aerial survey method we are going to need the same type of experienced observors we are now using in the airplane, particularly if the job is to be done on a visual basis; (2) A photo interpretor with previous experience in detecting insect damage from conventional aerial photos has a definite advantage over a straight photogrammetrist. In other words, he knows better what to look for. We also feel that the U-2 underflight support greatly improves efficiency of detection and except for rare instances, can eliminate the need for any other underflight photography.

We are still a long way from achieving our original objective, but we feel that we are making progress even though it is slow.