Infrared Aerial Photography — Easier Than You Think!

By W. E. Wildman and J. K. Clark

William Wildman (pilot) is soils specialist and Jack Clark (with camera) is photographer with the University of California Cooperative Extension at Davis. Wildman became interested in aerial photography several years ago, taking his own pictures while piloting the plane. In 1973, he teamed up with Clark to assess the value of low cost infrared aerial photography as a management tool. They have taken over 9000 paired color and infrared slides of a variety of crops and landscapes throughout California.

YOU'VE HEARD of infrared. Maybe you don't know quite what it means, but you've seen some curiously beautiful pictures with shades of red where green plants ought to be. You've heard that it's a new kind of photography that promises to discover plant diseases and other problems before you can see them with your eyes. Let's look at this interesting new tool, see in simple terms how it differs from ordinary photography and find out how it may be useful to us.

First, what is infrared, anyway? Briefly, infrared is a part of the broad energy spectrum which starts at the short wavelength end with cosmic rays, gamma rays and X-rays. A little way up the wavelength line comes ultraviolet radiation, then with increasing wavelength, visible light, infrared, microwave and finally the long radio waves. Scientists don't yet understand all they know about this electromagnetic spectrum, but that doesn't stop it from being enormously useful to us in many ways.

Visible light covers only a small part of the total energy band. Infrared covers a much broader portion, and herein arises a source of some confusion. A large part of the infrared band, the so-called "thermal infrared," is the result of heat emitted from objects. Infrared color or black and white films do not record thermal infrared, but are sensitive to the "near infrared" radiation which is reflected from objects. The near infrared reflectance is not a function of the temperature of the object. If it were, green plants would be the warmest things in the picture, and we know this is not the case. Some people prefer to call this radiation "photographic infrared." If our eyes were sensitive to it, we might see it as an additional color.

To understand the similarities and differences between ordinary color film and infrared color film, imagine a color picture of a girl resting on a hillside. Ordinary color film is sensitive to the complete visible spectrum and contains three layers sensitive to blue, green and red light. Dyes formed in these layers during processing produce a true color image. Visualize the various colors in the picture — green grass, blue sky, the girl is holding a red flower and wearing a blue cap.

If you were to look at an infrared color picture of the same scene, the most striking difference would be that the green grass is now red. You would also notice that the red flower is now yellow, and the blue cap is red. This is called a false color image. The film is recording only part of the visible light spectrum, the green and red bands, and is also sensitive to the near infrared portion of the spectrum. This film uses the same dye colors as ordinary color film but the dyes are developed by different wavelengths than they are in color film. Hence, false colors result in the final picture, and there is a purpose in this.

Healthy green plants reflect, in addition to green light, large amounts of near infrared radiation. Nothing else in the landscape reflects this combination of radiation. The false color assignment of dyes to sensitive layers of infrared color film results in green plants appearing in various shades of red.

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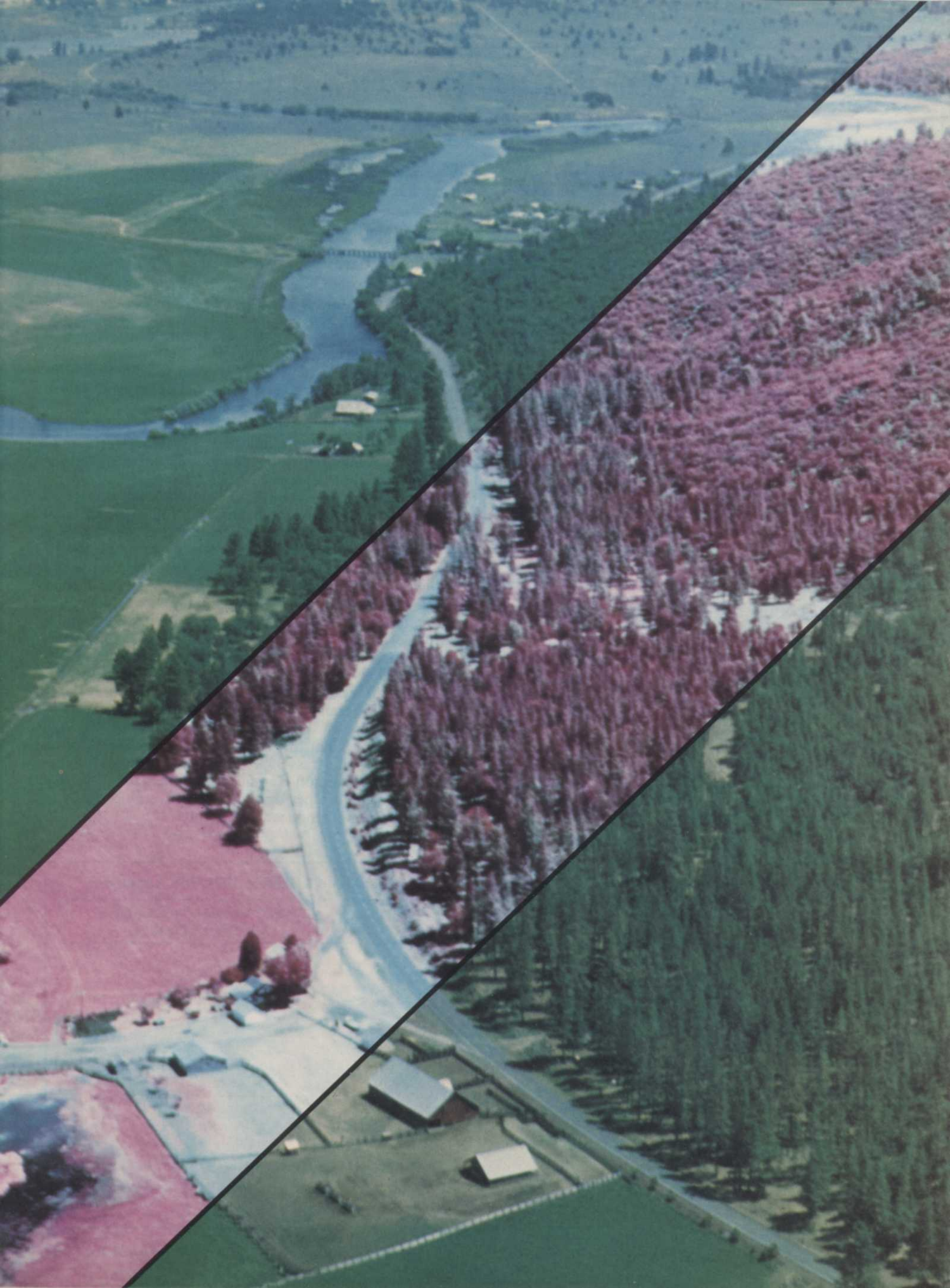
Right: This composite picture, made from ordinary color and infrared color slides, is the companion picture to the cover. Notice that the pine trees with a fungus disease are more easily detected in the infrared portion of the photo.

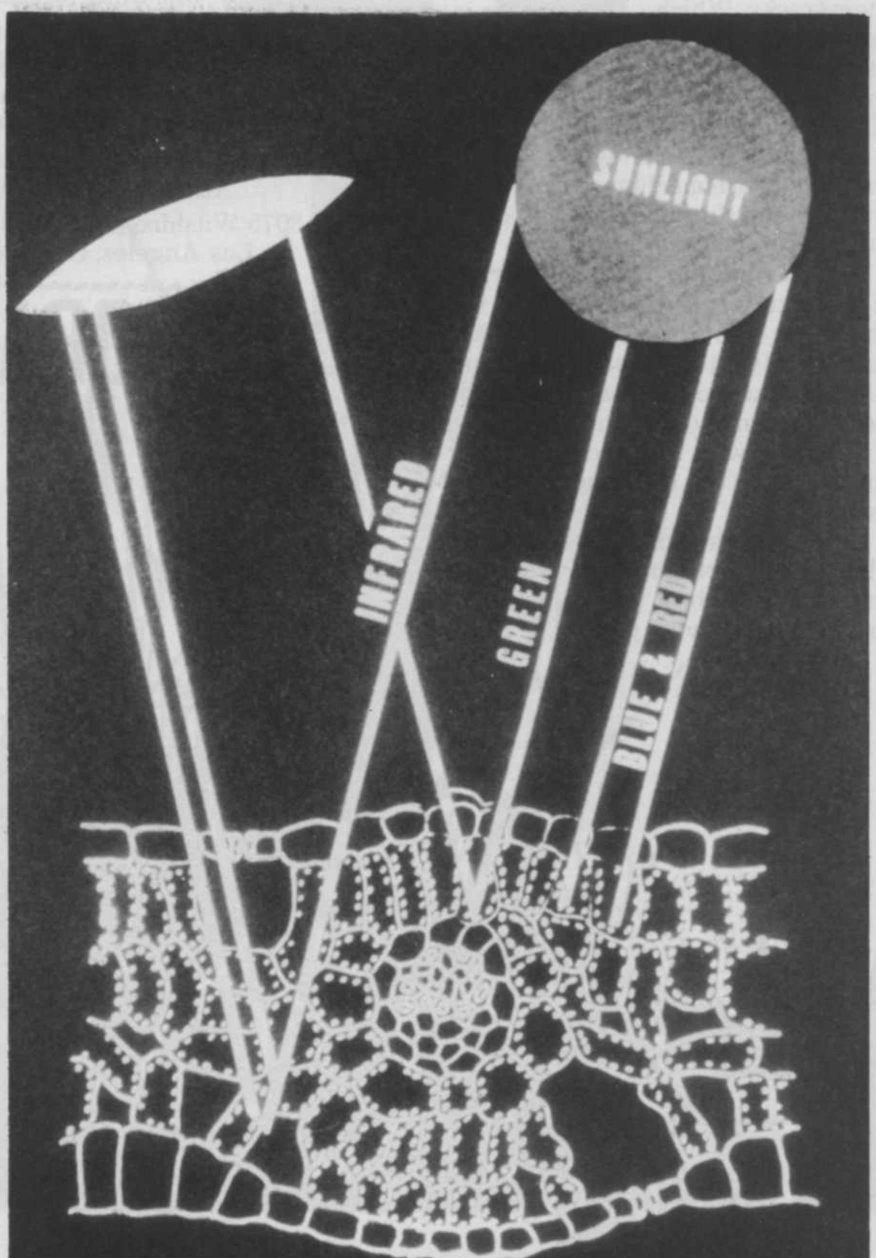


INFRARED *(from page 35)*

Naturally-red objects appear yellow or green. Green objects which are not plants do not reflect much infrared, therefore show in the final picture as purple. This effect enabled aerial photographers in the Korean War to detect camouflage which was painted green, and was the original reason for the development of infrared color film.

How can infrared color photography be useful to us? Anyone who deals with plant growth has a potential use for infrared color photography. Since plants reflect large amounts of invisible near infrared radiation, recording it on film may give us information about plant response that we cannot see with our eyes.

For example, consider the visible light and infrared radiation that comes from the sun and falls upon a green leaf. The blue and red wavelengths are largely absorbed by the chlorophyll in the leaf and provide the energy for photosynthesis. Green light is partially reflected and we see plants as a green color. Infrared is reflected from deeper in the leaf tissue, and in greater amounts than green light. Any disease or stress on the leaf tissue may cut down on the amount of infrared reflected, without changing the amount of green light reflected. When this happens, we may be able to spot an adverse condition by taking an infrared photograph before we can see the symptoms with our naked eye. This is called *previsual detection.*



When sunlight strikes a green leaf, blue and red light are absorbed and used in photosynthesis. Green light is reflected, giving plants a green color. Infrared is even more strongly reflected than green, but we cannot see it.

Can infrared photography be useful in everyday agricultural and environmental management? We set out to answer this question in the summer of 1973. Although a number of research studies have pointed out various specialized uses of infrared aerial photography, we knew of no one doing it commercially except on a high-priced, special project basis. We reasoned that if relatively inexpensive aircraft and hand-held 35 mm cameras could be used, the cost of aerial photography might be lowered to the point at which it could become a routine management tool.

To find out, we made monthly flights from April to October over the state of California in a rented Cessna 172. We asked county extension agents and university researchers to submit requests for aerial photos of crops or land uses of their interest. Our photographer made a simple frame on which he mounted two 35 mm cameras. Using a double cable release, both cameras could be snapped simultaneously to obtain matching color and infrared color photos of an object. At the end of the season we had accumulated 3,000 pairs of color and infrared photos of crops of all kinds, rangeland, forest and wild lands, urban and recreation areas. After polling the agents and researchers, we came to the conclusion that we had: (1) learned a great deal about some of the uses and techniques of aerial photography, and (2) barely scratched the surface of its potential applications. Here are some of the things we found out.

Aerial photography using any film can increase one's knowledge.

Patterns in soils and vegetation that are not readily apparent to the person on the ground show up clearly from the air. Even though a farmer may be aware of a thin spot in a crop, its size and shape are much more exactly defined by an aerial photo. Often an area of intermediate growth around the thin spot will prove to be much larger than the farmer realized by ground observation only.

Interpretation of aerial photos requires good ground information.

The site should be examined on the same day the aerial photos are made. As soon as the photos are processed, interpretation of patterns can be made from notes taken during the ground examination. Unexplained patterns may require re-examination of the site and perhaps collection of soil or plant tissue samples for laboratory analyses.

Color pictures are usually preferable to black and white. Infrared color photos may or may not give more information than color photos.

We like the matched color and infrared color photos because they give a record of how the scene looked to the eye, plus the possibility of greater interpretation from the infrared. Often we see the same patterns with each film, but they are usually plainer and more contrasting in the infrared picture. Only occasionally were we able to see patterns in the infrared photo that we could not see in the corresponding color one. Nevertheless, we think the infrared is valuable because of its greater contrast, and its greater ability to penetrate haze.

Nutrient deficiencies and non-uniform fertilizer application show up well.

Deficient yellow leaves in color photos appear white in infrared photos. The contrast between deficient leaves (which show up white) and healthy ones (which appear red) on an infrared photo is much greater than the contrast between the corresponding yellow and green leaves in a color photo.

Patterns of aerial fertilizer application, which is particularly susceptible to non-uniform spreading, are easy to trace in an infrared photo.

Sprinkler irrigation patterns are easy to spot.

Sprinkler-irrigated areas can suffer from non-uniform water coverage due to winds or improper system design. Patterns which are barely visible on the ground are amplified in the aerial view. Again, the infrared provides greater contrast.

Burned areas are particularly visible on infrared film.

The green living vegetation versus gray ash on color photos becomes red versus black on infrared.

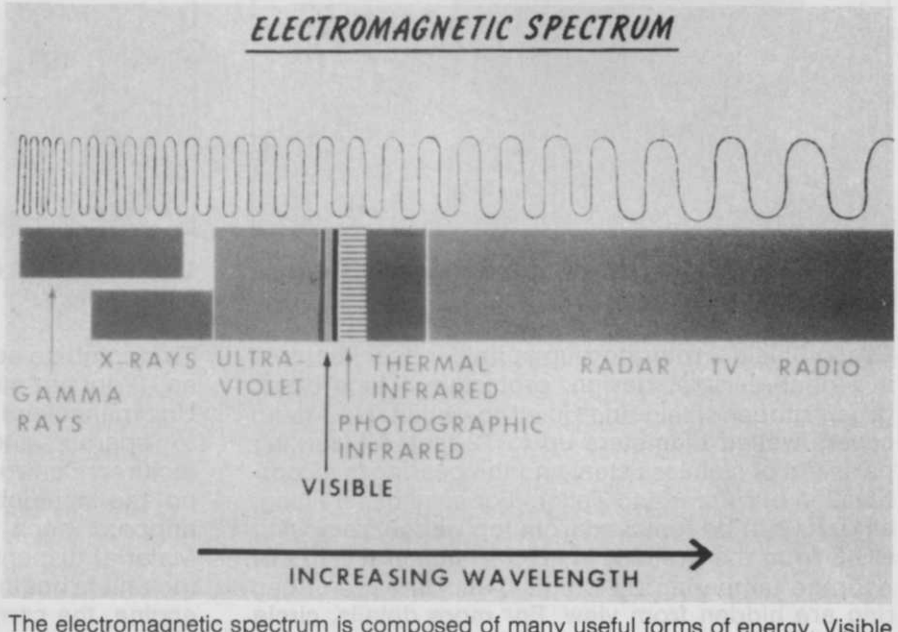
We did not accumulate much experience with diseases, insects or weed infestations. We think there will be times when infrared color photography will be invaluable in diagnosing the spread of these plant competitors. There may also be cases in which infrared will not be as much help as we would like. A great deal of work needs to be done on the photographic characteristics of many plants under controlled conditions including various kinds of stress.

On the operational side, we found it quite easy to get good aerial photos from hand-held 35 mm cameras. We recommend a high wing plane with a window which can be opened wide. (On Cessna 150 and 172 aircraft, a small brace can be disconnected to allow the window to swing up parallel to the wing.) Removing a door from the aircraft is not recommended for anything but short flights on warm days. A cold wind in the cabin is distracting to both pilot and photographer. Approximately vertical photos can be made by banking the plane about 45 degrees when directly over the photo site. However, oblique photos are often just as good, and are easier for both photographer and pilot.

A No. 12 or No. 15 Wratten filter or equivalent is used with infrared color film to filter out blue light. Exposure settings are more critical than for ordinary color film since light meters do not measure infrared radiation. You can come close, however, by setting your light meter at ASA 100. Take one infrared color picture at the camera setting your light meter calls for, and one each at the F-stop above and below this setting. One of your pictures should be properly exposed. Use a shutter speed of 1/250 second or faster for aerial photography.

Infrared color film requires some special handling because it is easily damaged by heat. Never allow the film to become warmer than ordinary room temperature. An afternoon in a hot car can ruin it. Ideally, the film should be kept frozen before use, and should be warmed to room temperature in the cannister (to prevent moisture from condensing on the cold film) a short while before use. The entire roll should be exposed in one day, the film removed and processed immediately. Try to assure that the film will remain cool while on its way to the processing laboratory. If a roll is not completed, it is better to waste the unexposed frames than to leave the film in the camera for another time.

With these suggestions, anyone should be able to take reasonably good infrared color aerial photos. A little experimentation on camera settings and aircraft altitudes may be necessary to obtain the best results. Almost everyone knows someone who flies, and most pilots will welcome an excuse to fly. Even if you have to charter a plane and pilot, the cost of an hour or two of flying may be cheap in relation to the usefulness of your aerial photos.



The electromagnetic spectrum is composed of many useful forms of energy. Visible light covers only a small part of the total energy band; a large part of the infrared portion of the band is thermal infrared.