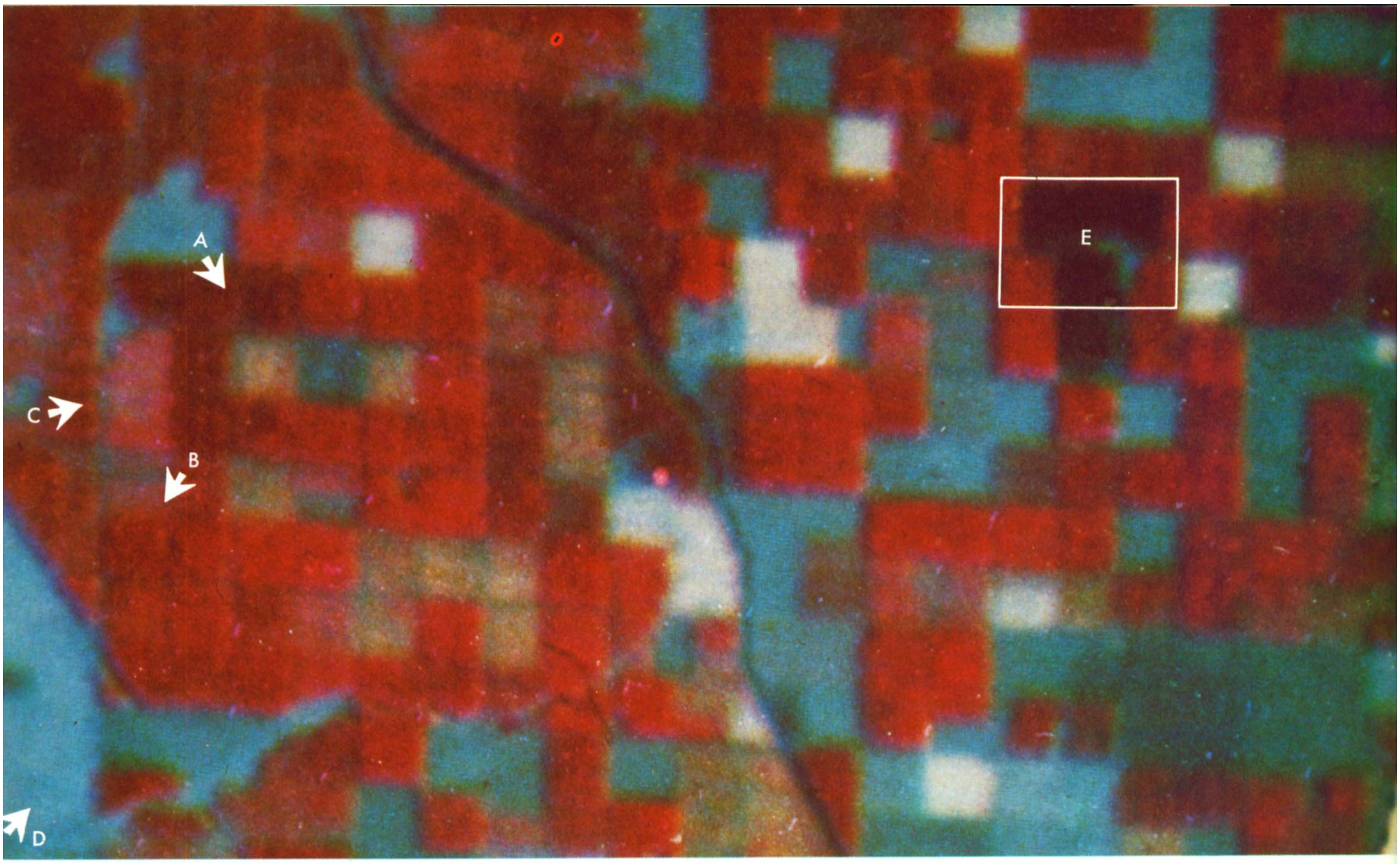
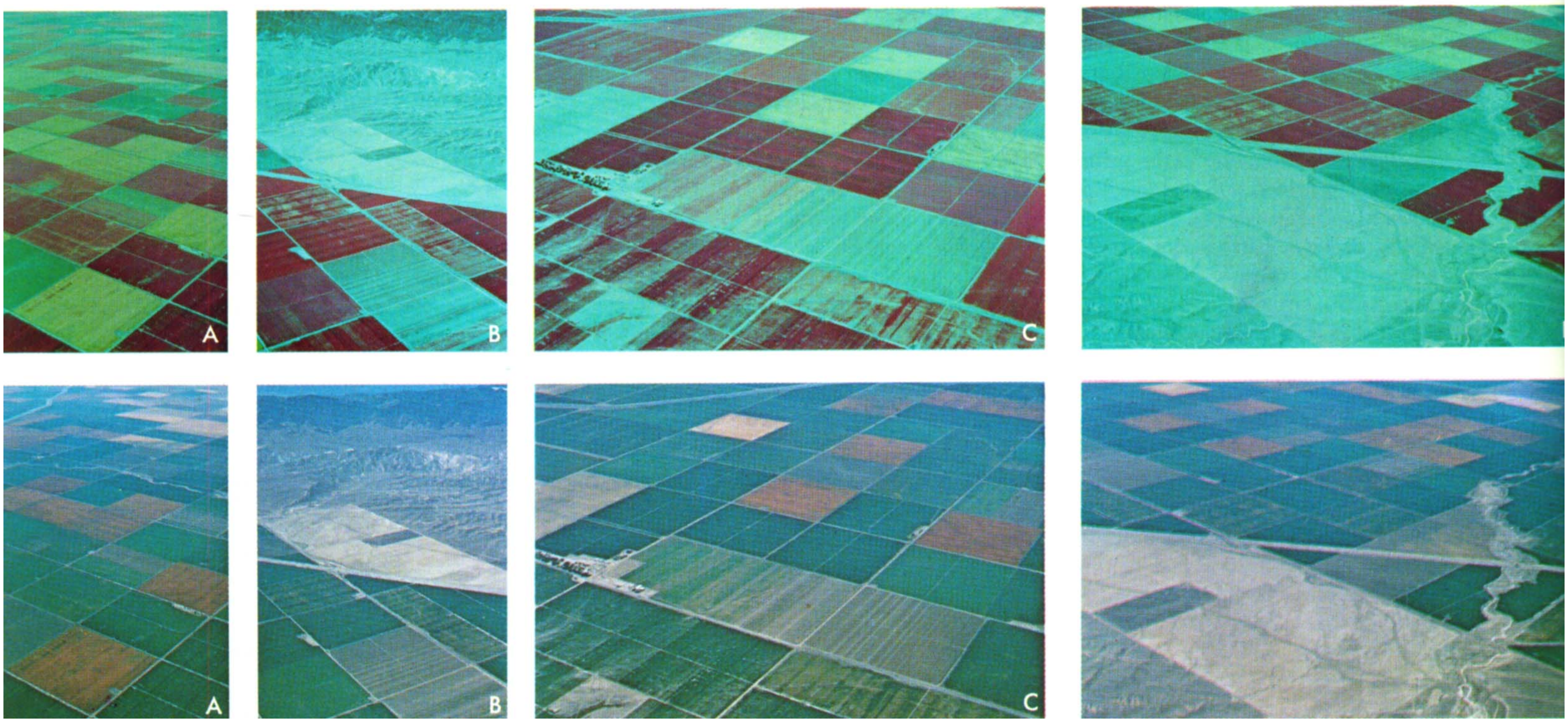


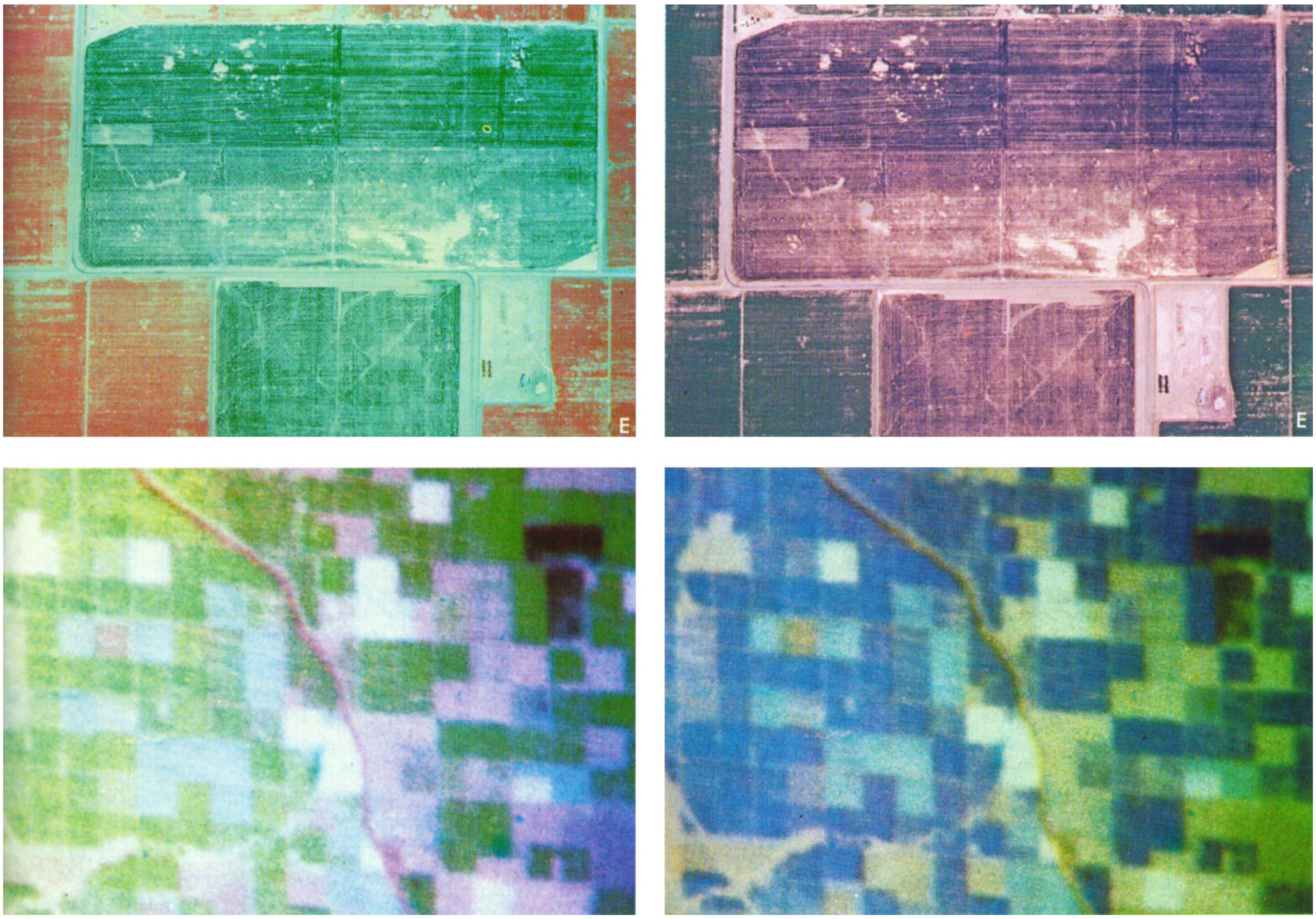


At the top is an enlargement of Area I as annotated on the cover photo. Although the photo was taken from an altitude of 570 miles, individual fields which are as small as 20 to 40 acres and also many linear features less than 100 feet across can be seen on it. Field checking showed that, in this photo, all yellow-appearing fields were barley; brown fields were safflower; black fields were recently burned stubble; blue-grey fields were fallow; and red fields were healthy green crops, mainly sugar beets and alfalfa. Arrows appearing on this space photo indicate the camera stations and camera orientations used in taking the accompanying aerial photos from an altitude of 10,000 feet. The four photos in the bottom row were taken with conventional Ektachrome film and show the fields in their true or natural colors. The four matching photos immediately above them were taken with Infrared Ektachrome film which, like the space photo, produces "false" colors. Note for example, that such film causes green vegetation to appear red. Annotations permit these photos to be tied to the top photo.

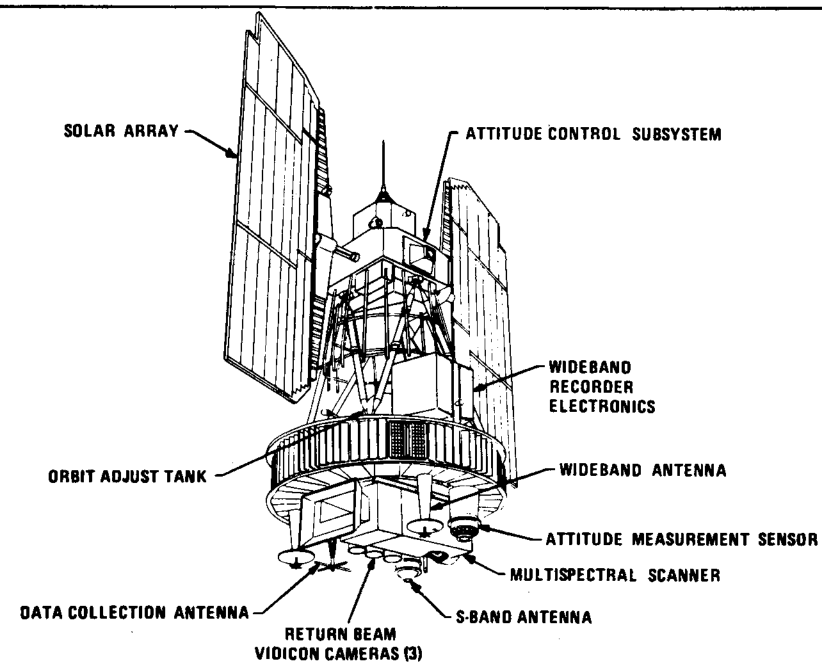
Space photography aids agricultural planning

ROBERT N. COLWELL

On July 23, 1972 the National Aeronautics and Space Administration launched its first Earth Resources Technology Satellite (ERTS-1), using launch facilities at Vandenberg Air Force Base near Lompoc, California. From an orbital altitude of nearly 570 miles this unmanned satellite is photographing all cloud-free portions of California every 18 days and will continue to do so for an estimated 12-month period. Scientists of the University of California, in cooperation with those from the California Department of Agriculture and other state agencies, are studying the extent to which information extracted from such photographs can facilitate the management of California's agricultural resources. As illustrated by the cover photo, each "frame" of ERTS-1 photography covers more than 10,000 square miles. Nevertheless, when such a space photograph is enlarged, agricultural features as small as 100 feet across can be discerned (see pages 8 and 12). Many crop types and rangeland conditions can be inventoried, and land use categories can be recognized on such space photos when supplemented with only limited amounts of aerial photography, and direct on-the-ground observation. Results obtained to date indicate that careful interpretation of sequential space photography of the type currently being obtained by ERTS-1 can greatly facilitate the monitoring of crop development and land use change, thereby facilitating the management of California agricultural resources.



Top pair of photos show Infrared Ektachrome (left) and Ektachrome views of Area E as outlined on the space photo at the top of the opposite page. These vertical photos, taken from an altitude of 10,000 feet, might well serve as components of the second stage in a "multistage sampling scheme" for the inventory of agricultural crops. Such photos would give additional details for representative areas, as selected from one or more space photographs covering the entire area. The third stage is a still smaller subsample consisting of direct on-the-ground observation of crop type, vigor class, and probable yield. Bottom photos show use of an "optical combiner" to form these two additional color composite images from the three separate black-and-white space photos (page 11). Comparison with the top photo page 8, shows that some features are better seen on one enhancement, while others are better seen on another. Such multi-enhancement techniques provide a new and very powerful tool for the analysis of agricultural crops through the use of aerial photographs.



The ERTS-1 spacecraft, shown here in diagrammatic form, is 10 ft tall and weighs approximately 2,000 lbs. It is in a near-polar "sun-synchronous" orbit and passes over California during the same mid-morning hour every 18 days. A 100-mile-wide strip that is photographed on one mid-morning pass is overlapped by a similar strip to the west of it on the following day. Data collection antennas on the spacecraft receive information from the ground on environmental conditions at various selected test sites.

As SKETCH above indicates, NASA's Earth Resources Technology Satellite (ERTS-1), is equipped with two camera-like sensor systems, a return beam vidicon (RBV) system, and a multispectral scanner (MSS) system. Both systems, through the use of properly selected color filters, are able to obtain black-and-white photographs simultaneously in each of several energy bands. Three such photographs (see top of opposite page) were obtained from ERTS-1 by the MSS system when exposing for energy in the green, red and near-infrared regions of the electromagnetic spectrum, respectively.

Comparison of the three photos with those on page 8 shows that each type of crop tends to reflect energy in these various bands in distinctive amounts—thereby governing the tone or brightness "signature" of the crop as seen on the various bands of photography. It follows that interpretation of several bands of photography together, allows more elements of a crop's tone signature to be discerned, thus improving the accuracy of its identification.

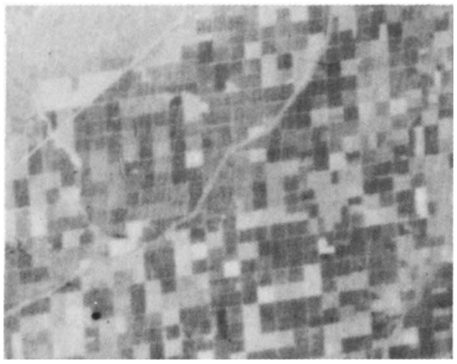
The interpretation of these photographs can be greatly facilitated if they are optically combined to produce various color composite images. For example, the "false color" photograph appearing at the top of page 8 was produced by projecting the three photos on the opposite page through blue, green and red filters, respectively. Although most agricultural features are best interpreted using this particular color scheme, it will be seen from the bottom two photos on page 9 that some features are better seen by projecting these same three black-and-white photos through other filters which produce decidedly different false color renditions.

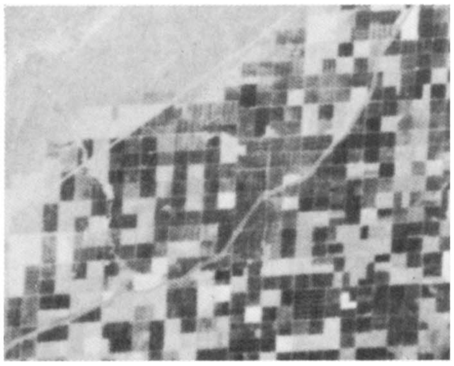
Because of the tremendous data-collecting capability of Earth Resources Technology Satellites, much concern is being expressed regarding the ability of photo interpreters to analyze such vast quantities of data. Consequently there is growing interest in the possibility of assisting humans in this Herculean task through various kinds of "automatic data-processing" that are achievable when modern computer techniques are used. One example of this capability is illustrated in the lower photo on the opposite page. By comparing that example with the same area as seen on page 8, it can readily be seen that safflower, by virtue of its unique "spectral signature," has been programmed to print a unique symbol on the computer output sheet.

The computer also can be commanded to maintain a running total of all symbols of this particular type that are being printed out. The area of agricultural land that is represented each time this symbol is printed can readily be determined. Multiplying this "unit area" by the number of symbols of this type thus provides a ready indication of the total acreage of safflower in any specified agricultural region. In order to convert this total *acreage* to total *yield* of safflower, on-the-ground measurements must be made to determine the average yield per acre.

Conceivably such a technique could be developed for each type of crop, thereby providing statistics on its probable yield, county-by-county and region-by-region. At the start of the growing season in any given year, preliminary estimates of crop production could be compiled through the use of ERTS imagery acquired at that time. Later, such estimates could be quickly updated at 18-day intervals (corresponding to dates for the successive ERTS-1 overflights) throughout the growing season.

Some enthusiasts believe that timely information of this kind could lead to greatly increased efficiency in the programming of several agriculture-related activities. For example, they believe that year-after-year, a better and more timely determination could be made of (1) the quantity of each type of fertilizer, fungicide, insecticide, herbicide and other chemical that will be needed in producing each type of crop; (2) the number of laborers that will be needed to harvest the crop and when they will need to be available; (3) the number of trucks, railroad cars and other transportation facilities that will need to be programmed for the harvesting and marketing activities and (4) the quantity of containers, preservatives and related supplies that will be needed in processing the crop.





These three black-and-white images were obtained by the ERTS-1 multispectral scanner system in green, red, and near-infrared energy bands, respectively. Note tendency for each type of crop or field condition to show three-band "tone signature" as explained in text.

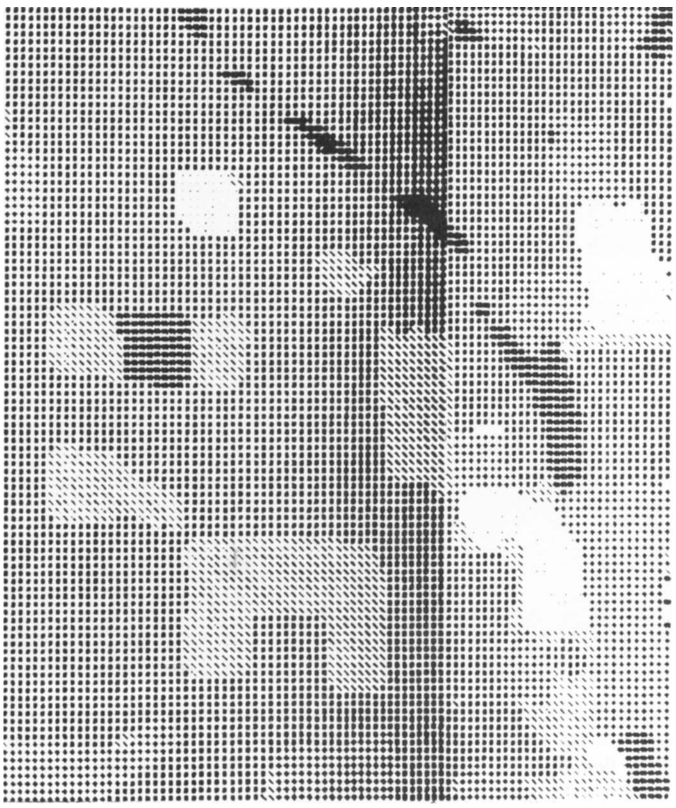
Others, while questioning the real value of such refined information, feel that great benefit to California's agricultural economy could result merely by improving the accuracy of our information regarding various kinds of land use in agricultural areas, such as the total acreage of irrigated farmland, of non-irrigated farmland, and of areas in an agricultural region for which significant changes in land use are in the process of occurring.

Still others feel that the major potential benefit of ERTS to California's agricultural industry might result from its ability to monitor snow-accumulation in the Sierras each year during the late fall and winter months as well as snow melt during the spring and early summer months, thereby providing more accurate information on water availability for agricultural use year-after-year.

Finally, there are livestock managers in California who believe that ERTS could monitor each year the progression from south to north of the "green wave" of forage as the annual grasslands respond to the fall and winter rains. Similarly they believe that ERTS could monitor the "brown wave" of forage as these grasslands respond to the onset of the dry summer season. Such information, they feel, might greatly improve our ability to determine both the volume of forage available for grazing and also the time of year when it might best be grazed, area-by-area, in conformity with certain well known principles which govern "range readiness."

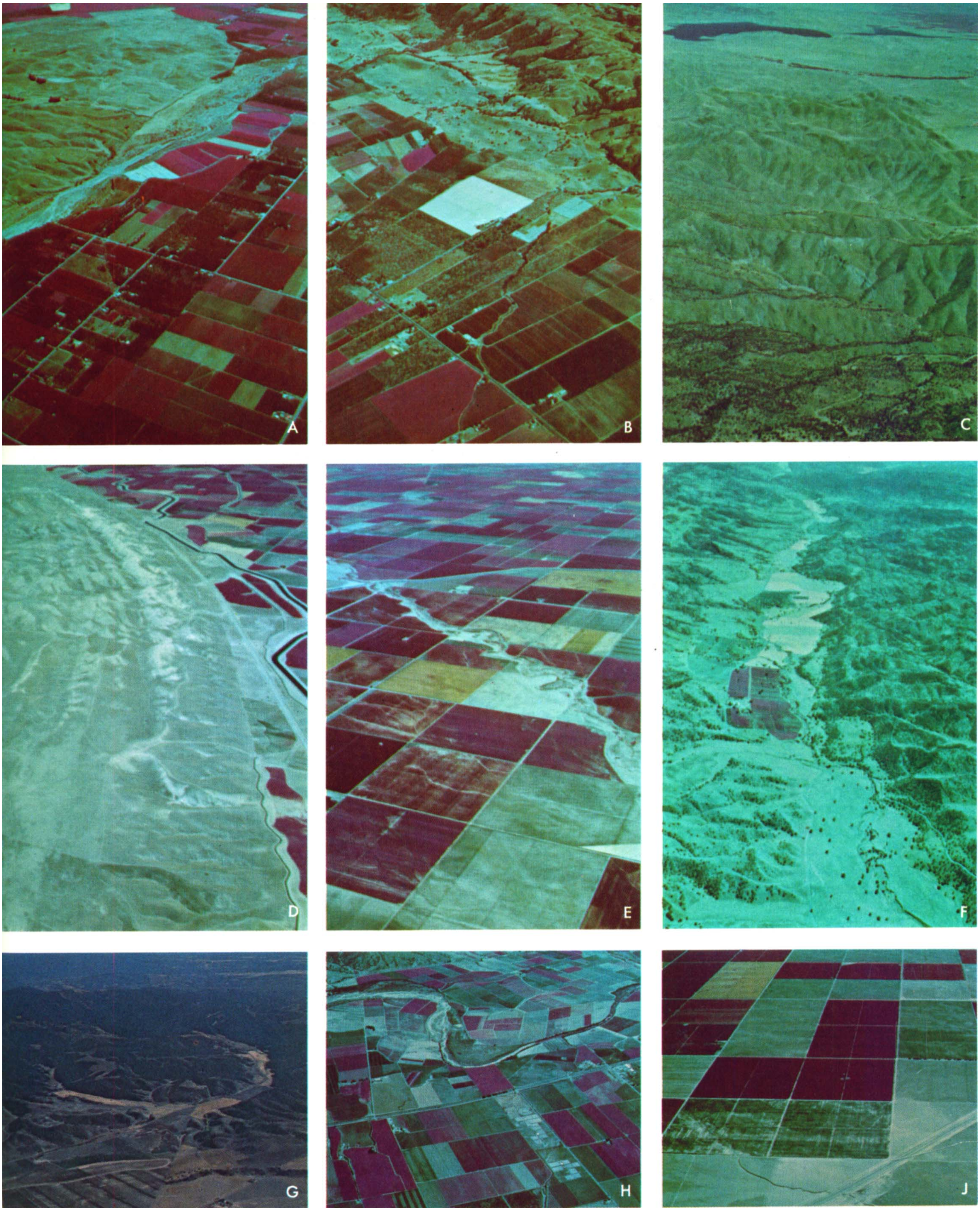
As the University's NASA-funded research continues, close cooperation with the previously mentioned state agencies and with the farmers and livestock managers themselves, will be maintained. This will ensure that the types of agricultural information found to be obtainable through the use of ERTS capabilities are those which show very real promise of being useful to California's vast agricultural industry.

Robert N. Colwell is Professor of Forestry and Associate Director, Space Sciences Laboratory, University of California, Berkeley.



Shown here is the "computer printout" of part of the area shown on page 8 which was made by scanning the corresponding black-and-white MSS images and programming the computer to print out a unique symbol for each of the five categories, plus water (total of six). Preliminary evaluation of this printout indicates that correct classification exceeds 95% in all six categories.

An enlargement of Area II is shown above, as annotated on the cover photo. As in the large photo on page 8, arrows appearing on this space photo indicate the camera stations and camera orientations used in taking the accompanying aerial photos from an altitude of 10,000 feet. Crop types and conditions in the annotated fields shown here are the same, but with the addition of rice, which is easily identified, field-by-field, from observation of its unique red coloration.



These nine aerial oblique photos are of the areas indicated by annotations appearing on the cover photo. For further explanation, see text.