Fig. 1. Uniform irrigation on nonuniform soils causes wide maturity variations. An additional main line would allow irrigation to match soil properties and produce a more uniform product.

Fig. 2. Trenching every fourth vine row to place irrigation pipelines loosened a severely compacted soil and produced an unexpected benefit in young vine growth.

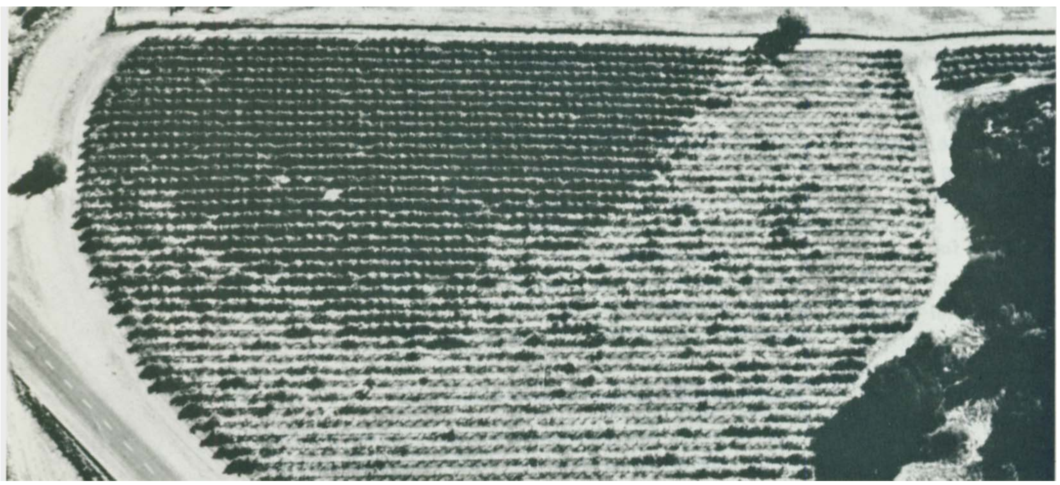


Fig. 3. Uneven application of nitrogen fertilizer on rice is very evident from the air.

# LOW-COST AERIAL for Agricultural

WILLIAM E. WILDMAN • RUDY A. NEJA

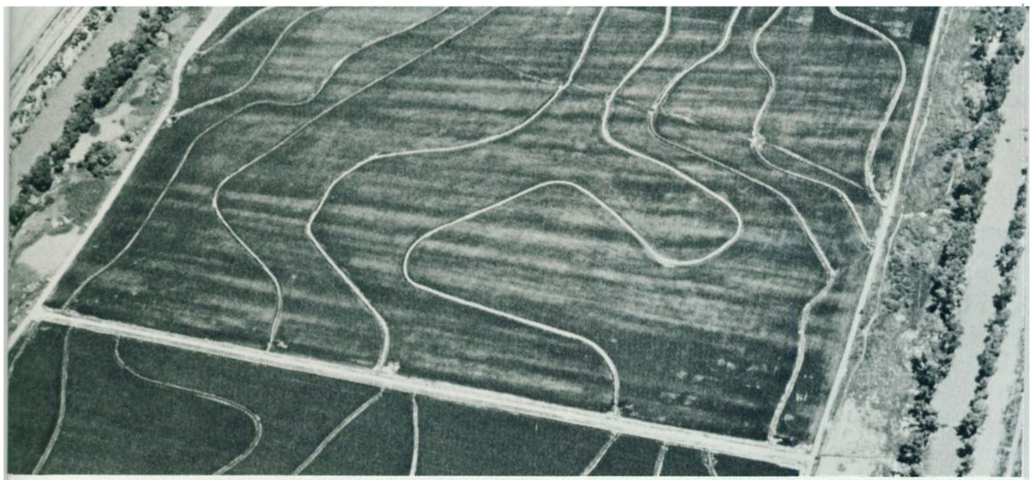
Any agriculturist viewing California croplands from an airplane at low altitude must be impressed by the broad view he gets. Entire fields, from 10- to 640-acre blocks, may be seen in one glance. Relative thriftiness of plants in various parts of the field are easily observed. Patterns of crop variation caused by nonuniform fertilization, irrigation, drainage, salts, soil texture, soil depth, disease, and insect damage are often more evident from the air than they are at close range on the ground. The economic severity of the conditions, however, must still be determined on the ground by measuring such factors as plant growth, crop yield, product quality, and, ultimately, net return.

We became interested in the potential of low-cost aerial photography—using relatively inexpensive planes and hand-held 35 mm camera—when it appeared that we could use this method to illustrate radical differences in grapevine growth caused by varying soil depths in vineyards.

After about five years experience, we conclude that aerial photography can be a useful tool in at least the following areas: 1. education; 2. evaluating land for future vineyards or orchards; 3. compiling crop histories; 4. monitoring experimental plots; and 5. diagnosing plant problems.

### Educational uses

Aerial photos of coastal valley vineyards have been most useful in Extension educational programs to illustrate soil and crop variation within the same vineyard block. Nonuniform vine growth often corresponds with varying soil depth or texture. Aerial photos emphasize the nonuniformity, convincing the grower that a change in management practices in exist-



# PHOTOGRAPHY
# Management

• JACK K. CLARK

ing vineyards should improve yield and quality, and that soils of future vineyards should be thoroughly investigated before planting.

Photos taken during the harvest period show the greatest contrast because vines that are drying and defoliating in shallow soil (cover photo) or coarse textured soils (fig. 1) differ greatly from vines that still have lush green foliage growing on deep- or medium-textured soils. Since these contrasting soil depths or textures can occur side by side along permanent sprinkler irrigation runs, large differences in yield and quality often result. To optimize production and quality in such vineyards, a change in irrigation management may be sufficient—for example, irrigating lightly and frequently, varying sprinkler nozzle size, or, in extreme cases, plugging the nozzles in areas of deep soil. However, in some vineyards, redesigning the sprinkler system may be required to allow blocks of soil to be irrigated separately from greatly contrasting areas nearby.

Too often, a grower may have recognized a problem from ground observations but let it remain uncorrected because he thought the area affected was relatively small. Aerial photos often show gradations in growth that indicate the problem is more extensive than the grower realized.

### Evaluating land for future crops

A grower considering a permanent crop should carefully examine the potential site before planting. Aerial photos of bare soil or previous crop growth can show soil variations that should be investigated on the ground by such means as digging backhoe pits. With detailed information on variations in soil depth and texture, the grower is better prepared to plan the layout of blocks of trees or vines to match the most uniform soil areas. He can design irrigation systems to provide the appropriate water application rate and frequency for each individual block. If the soil profile contains shallow compaction or deep restricting layers, he can apply deep tillage or modification treatments before planting that would be difficult or impossible to do after the permanent crop is in. (See fig. 2.)

### Crop history

Growers of certain crops would benefit by having aerial photos taken at least twice annually. The first photos should be taken in early midseason when crop growth is normally vigorous and uniform. Corrective measures can then be taken if crop nonuniformity is due to variations in irrigation, soil fertility, or pest control.

A second set of photos taken when part of the crop plants are drying up while others remain green usually gives the most information about differences in soil waterholding capacity or root damage by soil pathogens. These photos are most useful in determining whether any major operations (deep tillage, fumigation, or changes in management such as irrigation design or scheduling) will significantly improve growth in the following years.

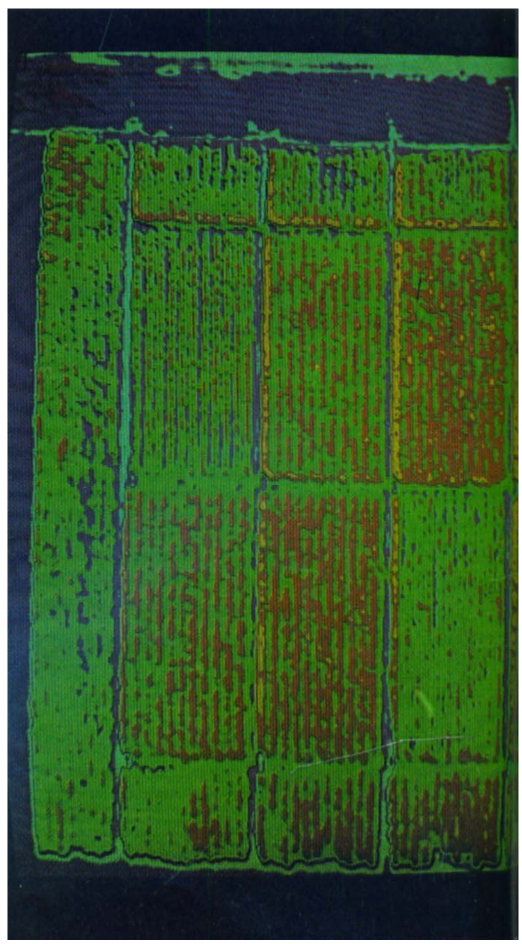
Aerial photos taken each year provide a record of crop performance and can be used as a means of improving management practices and justifying their costs. Mistakes made in crop management are often painfully obvious from the air (fig. 3). If the photos result in improved management, their relatively small cost should be returned many times.

### Monitoring experimental plots

It is useful to photograph experimental plots from the air periodically during the growing season. Our photos of vineyard experiments have provided visual proof that vine growth in plots given a light, frequent irrigation based on

Figs. 4a and 4b. Color infrared photos (left and right) of corn experimental plots at the Kearney Horticultural Field Station are superior to ordinary color photos in differentiating six different levels of nitrogen fertilization. By analyzing infrared photos with sophisticated instruments, it may

Fig. 4c. Slight differences that are undetectable to the eye may be made visible by electronic image enhancement. After electronic image enhancement of fig. 4a, all six N levels are clearly differentiated.



tensiometer readings is better controlled than growth in plots given heavy, infrequent irrigations with an early cutoff based on a calendar schedule.

By analyzing infrared photos of experimental plots with sophisticated optical instruments, correlations of plant health with color tone might be developed and used as standards for prediction of commercial crop performance. However, many photographic and plant growth variables would have to be considered if workable standards were to be developed. (See figs. 4a, 4b, and 4c.)

### Diagnosing plant problems

Because most of our photos were of known plant problems, we seldom diagnosed the causes solely from the photos. However, as aerial photography comes into more common use for crop management, we expect that both the diagnosing of plant problems and monitoring effects of corrective measures will be increasingly important benefits. Fig. 5 shows one example in which the photos did pinpoint the cause of irregular vine growth.

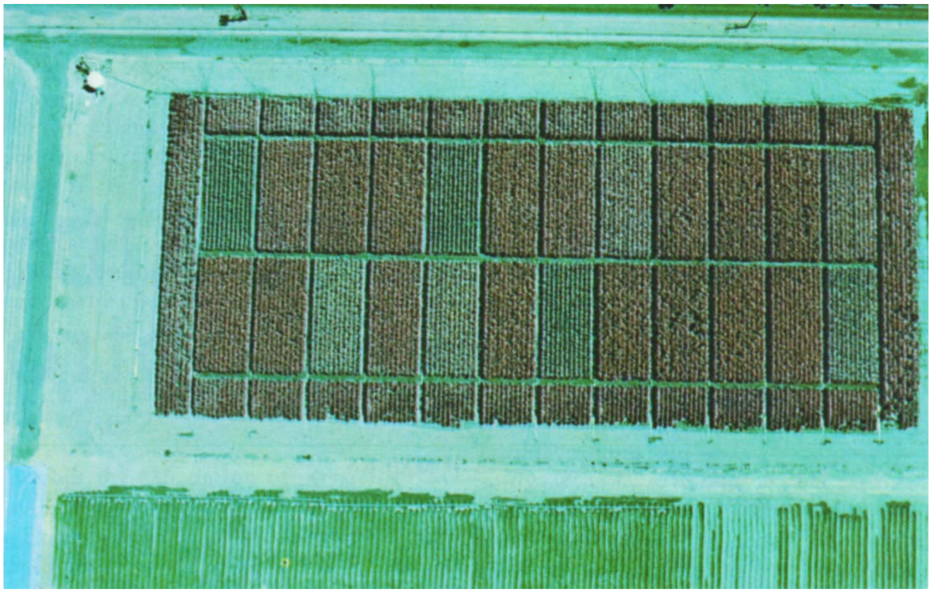
The differences between ordinary color and color infrared film are not as dramatic as first expected. But color infrared film often shows *visible* differences in crops or soils more plainly than color film, and gives clearer pictures because of its greater inherent contrast and haze penetration (because of filtering out of the haze-scattered blue light). If we didn't have the color infrared, we might miss some differences which, though visible, are obscure on color photos.

### Taking the photos

Useful aerial photos can be made using relatively inexpensive cameras and aircraft that are readily available to growers, agribusinesses, and researchers.

We used two 35 mm single lens reflex cameras, mounted on a single frame with a pistol grip handle and a double cable release activated by a single plunger. One was loaded with color film, the other with color infrared. They were placed as close together as practicable and were aligned to frame exactly the same scenes. A No. 15 (Wratten or Tiffen) filter on the camera containing the color infrared film filtered out blue light for a proper color balance. Standard 50 to 55 mm lenses were used most often, and the aircraft was flown at the altitude required to frame the picture desired; however, for very large fields and on hazy days, 28 mm lenses reduced the altitude required for the picture.

At very low altitudes, the apparent speed of the ground can cause blurring, so fast shutter speeds (1/500 or faster) are necessary. On the other hand, very small fields may be more conveniently photographed using a telephoto lens at a higher altitude. Care must be taken, since any



be possible to match a particular color with a certain nitrogen level--potentially a very useful management device. However, many other variables that affect the color tone would have to be kept constant.

motion of the camera will be magnified by a telephoto lens.

Exposures for color infrared film are not readily obtained using ordinary light meters. However, a light meter set at ASA=100 can give a first approximation. Several exposures should be taken at half and full stop intervals above and below the light meter reading, until one has had some experience with the film and camera. Decreases in radiation due to low sun angles or cloudiness make it difficult to estimate the exposure, requiring more than normal bracketing.

Color infrared film does not record heat differences, but is nevertheless subject to damage by high temperatures. Even at normal room temperature, the film dyes change with time. To maintain the most consistent results, the film should be kept frozen until just before use, and then allowed to warm to room temperature before removing from the cannister to avoid condensation of moisture. Color infrared film should be exposed within a short period of time, removed from the camera, and refrozen before sending to the processor, if possible, in a styrofoam chest containing cold packs.

Various light aircraft may be used but some are more convenient than others. For occasional photography where no modification of the aircraft is desired, we find high-wing planes in which a window can be open wide to be the most versatile.

The procedures outlined will enable almost any agriculturist to take useful photos for crop management. However, commercial or research photographers who require high resolution aerial photography should install specially designed aerial camera equipment in planes modified for the purpose.

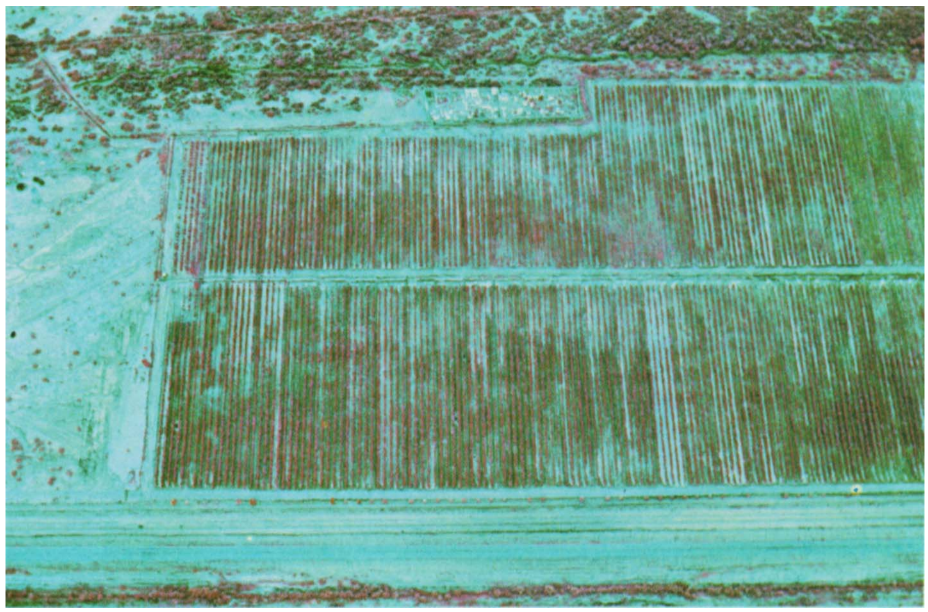


Fig. 5. Diagnosis of a vineyard problem was made by taking aerial photos a few days after flood irrigation. Small vines at the ends of the rows correlated with dry surface soils, while large vines at the centers correlated with soil that was still moist at the surface. Apparently improper leveling allowed most of the water to infiltrate the centers.

We have just scratched the surface of possible applications of low-cost aerial photography to agricultural and environmental management. Much more research is needed to match the responses of different crops and native species with different environmental conditions, and with the resulting characteristic "tone signatures" on color and color infrared films.

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