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Agricultural Inventory Techniques with Orbital and High-Altitude Imagery*

Such techniques can be included in present data-gathering systems to increase their accuracy and timeliness, and to decrease the amount of effort involved.

Abstract: *The objective of the research reported herein was to develop techniques based on the use of orbital and high-altitude aircraft imagery which could supplement present agricultural data-gathering systems. The techniques developed were tested in prime agricultural regions using procedures which approached operational conditions. Results of the tests indicate that orbital imagery offers a feasible alternative to conventional photographs for making "first cut" stratifications and general land-use mapping, and orbital imagery allows land-use information to be collected more frequently than can be done efficiently with conventional photographs. For acreage determination of a specific crop, interpreters using high-altitude sequential photographs, achieved accuracies comparable to those of present operational data-gathering systems. Therefore, it is considered that orbital and high-altitude aircraft imagery could be used in conjunction with present sampling systems to increase their efficiency and accuracy.*

Introduction

It has long been recognized that agricultural statistical information concerning crop acreages, yields, and prices is of definite importance to the farmer and agri-businessman. Farmers armed with information about the quantity, quality, and prices of agricultural products going to market, and agri-businessmen cognizant of similar facts, can make more confident decisions concerning the management of their respective farms and businesses. The more accurate and reliable the information, the less the risk involved in the marketing of agricultural products. Less risk leads to more stable markets and higher price returns for the farmer.

In recognition of the advantages to be gained by all, nationwide crop reports were begun on a regular basis in 1866. The task grew and evolved so that, starting in 1956, the Statistical Reporting Service of the U. S. Department of Agriculture began conducting enumerative surveys of agriculture twice a year. Not only does the Statistical Reporting Service (SRS) collect agricultural crop statistics, but numerous other federal and state agencies likewise find the need to collect and use similar information in their programs. For example, water resource agencies are often interested in acreages of crops, such as alfalfa and corn, that are high water consumers. By knowing the acreages of these crops, water resource agencies can better plan existing and future water projects. In addition, as most planting decisions are influenced by the availability of water, irrigation projects also need information on cropping practices to determine user allotments for a given growing season.

The purpose of the research reported upon herein was to develop techniques, using remote-sensing data, for the collection of more accurate or more timely agricultural land-use information. First the feasibility of using satellite imagery for land-use stratifica-

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tions was to be investigated and compared with the present operational systems. Stratification systems currently rely on conventional aerial photographs, and are often incorrect due to out of date photography. It was hoped that satellite imagery could provide a means whereby changes in land use could be quickly detected and incorporated into more frequently updated stratifications.

Second, the level of accuracy obtainable in a crop inventory for a specific crop using high-altitude aircraft photographs was to be determined. The best type and date/s of photography for the inventory were to be determined and a comparison between two highaltitudephotographicsystems,namelyan RC-8, 9 × 9-inches format, 1:120,000-scale system and a Hasselblad, 70 mm format, 1:450,000-scale system was to be made and quantitatively evaluated.

FIG. 1. Two leading agricultural areas (cross-hatched on outline map) were used as test sites for the development and evaluation of agricultural inventory techniques using orbital and high-altitude aircraft imagery. one area was San Joaquin County, California which is an important field crop, deciduous fruit and nut crop, and vegetable crop area with an annual gross production value of over 170 million dollars. The other test site was Maricopa County, Arizona which is also a leader in field crop, citrus, and vegetable crop production with gross production values approaching 120 million dollars a year.

Test Sites

Agricultural inventory techniques using orbital and high altitude aircraft imagery were evaluated on two test sites within leading agricultural areas. Figure 1 is an outline map showing the location of these test sites. One area is San Joaquin County, California. This test site was established in the summer of 1971 when 48 ground-data cells of approximately 4 square miles each in area were distributed randomly throughout the 900,000 acres of the county. These ground-data cells were visited regularly (often monthly) since August of 1971. Crop information consisting of type, condition, height, percent canopy cover, and row direction has been collected on a field-by-field basis within the established plots. This field information is used to (1) build a crop calendar for the test site, (2) train interpreters, and (3) calculate error factors in interpretation tests and crop inventories.

The second test area is Maricopa County, Arizona. This county ranks high in the nation for agricultural production and contains 500,000 acres of irrigated agriculture. Work was begun in the Maricopa County site in March of 1969, and has resulted in four years of crop data collected on a field-by-field basis for 35 ground cells (Benson, et al., 1971).

Cropland Stratification Techniques Using Satellite Imagery

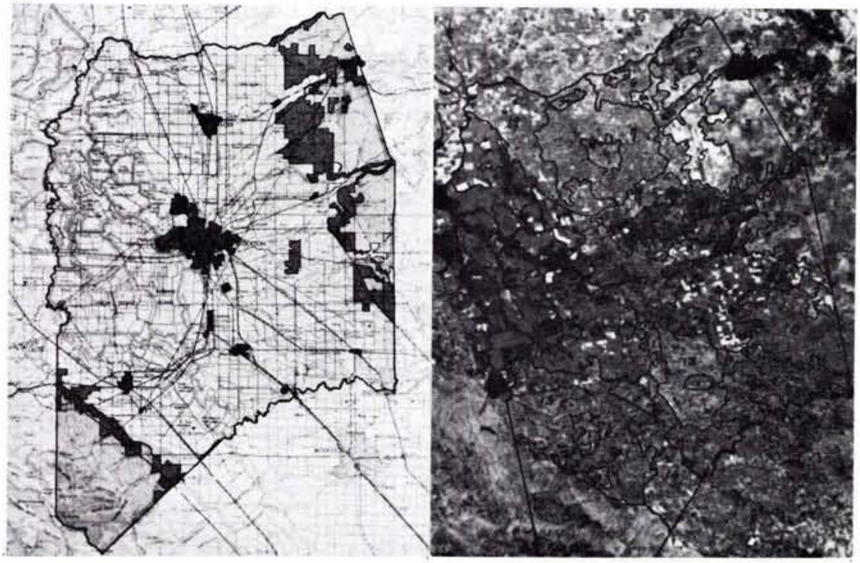
At present a statistical information gathering system, such as the Statistical Reporting Service's uses a statewide stratification system as a first step in the allocation of ground samples. The purpose of stratification is to improve sampling efficiency by decreasing the variance within a set of samples so that more precise estimates can be made from those samples. Within each stratum, sample plots are chosen and classified by ground personnel as to crop type, acreage in that crop, intended use of that crop, intentions of double cropping, etc. Also additional sampling data is gathered through the use of questionnaires sent to voluntarily subscribing farm operators. All of this information is weighted and expanded to the total stratum from which it was gathered; then a statewide as well as a nationwide estimate is derived. The accuracies obtained on a national level have 1 percent to 2 percent sampling error. This error is somewhat larger at the state and county level. Although no data are available to calculate the error, SRS personnel estimate it to be between 10 percent and 20 percent. Agricultural information generally is compiled and published once or twice a year by the SRS; usually there is a mid-year report around July first and a final report at the end of the year.

Stratification is now done on conventional aerial photographs and is often up to eight years out of date. The Statistical Reporting Service's stratification for San Joaquin County is shown in Figure 2A. This stratification is currently in use by the SRS as part of their operational sampling program for enumerative crop surveys. There are five different land-use strata within the county according to this stratification: urban areas, non-agricultural areas, irrigated agricultural areas, dryland agricultural areas and the range-land areas. This stratification is at present out of date. For example, lands classified as dry-land agriculture have been in one instance inundated by a man-made reservoir, and in another instance taken over by irrigated agriculture.

These examples show that such stratifications if prepared from outdated conventional photographs can quickly become inaccurate. However, the large number of conventional 9 × 9-inches, 1:20,000-scale photographs needed to cover an area the size of San Joaquin County without stereo overlap is more than 177 frames, and the number of frames needed to cover the state of California would be close to 20,000; thus to photograph and restratify the nation more often than every eight years becomes a fantastically time consuming task. For this reason satellite imagery with its synoptic view, and possibility of more frequent coverage, seems to offer a solution to the problem of out-of-date stratifications.

In July of 1972 the Earth Resources Technology Satellite (ERTS-1) was launched by NASA. On board were three return-beam vidicon (RBV) cameras and a four-channel multispectral scanner. This satellite has been returning imagery of any given site within the U. S. every 18 days, weather permitting. Imagery from this satellite taken on July 26, 1972 of the San Joaquin County, California test site was used in evaluating satellite imagery for land-use stratifications.

Contrast the SRS stratification (Figure 2A) with one prepared from a portion of the enlarged ERTS-1 color composite for the same area as illustrated in black-and-white in Figure 2B. The area imaged on the full ERTS frame was approximately 100 miles square, but only one-eighth of the frame was required to cover San Joaquin County. The stratificaton was done by three interpreters working independently of one another and each one took no more than 45 minutes to complete the task. Upon comparison of the individual stratifications, they were remarkably similar and there were no major differ-



2A 2B

FIG. 2A. A portion of the most current Statistical Reporting Service's stratification for California as it appears in San Joaquin County. It contains five land-use strata: Urban areas (*1*), Non-agricultural areas (*2*), Irrigated agricultural areas (*3*), Dryland agricultural areas (*4*), and Rangeland areas (*5*).

FIG. 2B. A portion of an enlarged ERTS-1 composite covering San Joaquin County taken on July 26, 1972. Interpreters were able to define 17 land use strata; 2 Urban Non-agricultural strata, 2 Rangeland strata, and 13 Agricultural land-use strata. See Table 1 for a description of the various strata.

ences in boundary locations. Two of the interpreters had virtually no ground familiarization with the area but the third was very familiar with the area, having performed ground data collection within the test site.

Instead of only 5 land-use classes as occurs in the SRS stratification, the stratification from the ERTS-1 image has 17 different strata. Differences between strata were determined by differences in field sizes, differences in field color proportions, and actual colors of fields and areas. A description of the 17 strata is shown in Table 1. The descriptions are based on field experience and data from the 48 ground data cells. Under the SRS's stratification system for San Joaquin County, there are only two strata for agricultural land, namely dryland agriculture and irrigated agriculture. In the stratification from the ERTS image it was possible to differentiate 13 different strata within the agricultural area. Orchard areas and vineyard areas could be separated from field crop areas; further differentiation could be made within field crop areas based on field sizes and field color proportions. The differences seem to indicate different predominant field crops within these areas. Most of the strata boundaries are closely tied to major soil type boundaries so that agricultural land use in San Joaquin County is directly determined by soil type and soil characteristics. Strata differentiated to this degree of detail could help to improve efficiency in any further sampling scheme.

TABLE 1. DESCRIPTION OF LAND-USE STRATA USING ERTS-1 IMAGERY.

Stratum Number	*Predominant LandUse*
1	Urban and city areas; non-agricultural cultural features such as military depots, airports, and sewage treatment facilities.
2	Rangeland located in steep topography.
3	Rangeland on rolling topography, some improved grassland.
4	Non-agriculture: water bodies, (natural and man-made).
5	Pasture and grains: dryland grain crops, irrigated pasture, and improved rangeland on rolling topography.
6	Pasture and grains: irrigated pastures, with secondary fruit orchards and vineyards.
7	Vineyards, with minor amounts of fruit and nut orchards, field crops, and irrigated pasture.
8	Fruit and nut orchards with minor amounts of field crops.
9	Field crops: small-grain crops (some non-irrigated) with an equal proportion of field crops (sugar beets, alfalfa), and some irrigated pasture.
10	Pasture and grains: Irrigated pasture and rice fields with some fruit and nut orchards and vineyards.
11	Nut orchards with some fruit orchards and vineyards.
12	Vineyards with fruit and nut orchards.
13	Field crops (safflower, beans, small grains, and alfalfa).
14	Field crops (beans, alfalfa, sugar beets, and small grains).
15	Field crops (sugar beets, corn and alfalfa).
16	Field crops (asparagus, corn, alfalfa, and sugar beets).
17	Irrigated pasture and field crops with minor vineyard areas.

CROP IDENTIFICATION AND ACREAGE ESTIMATION TECHNIQUES USING HIGH-ALTITUDE AIRCRAFT PHOTOGRAPHS

Remote-sensing data can further aid in agricultural inventories by the use of sequential high-altitude aircraft photographs for specific crop identification and acreage determination. The sequential technique was applied to Maricopa County to determine the acreage of the cotton crop.

IMAGE SPECIFICATIONS FOR A CROP INVENTORY

Past studies have shown that the ease and accuracy of crop identification can be maximized with the use of photographs flown at certain optimum times. For all crop types studied to date, it was found that a single date of photography was inadequate for identification and inventory purposes (Draeger, *et al.*, 1971). The most accurate inventory data was obtained using a combination of two or more dates of photography in a sequential technique whereby the phenological differences of a crop at different times in its growth cycle were used as identification characteristics for that crop. On any one date, two or more crops or field conditions may be at similar stages of development, such that the photo images will appear alike and be indistinguishable. This Group 1 of similarly appearing crops may be distinguishable, however, from another Group II of crops at a different stage of development. In the sequential technique, a second date, in which the characteristics and photo images of the crops in Group 1 are different and distinguishable, one from the other(s) in the group, is combined with the first date of photography. Thus by the use of two optimumly selected dates of photography the crop(s) can be uniquely identified and inventoried.

One tool which is helpful for the selection of optimumly timed sequential photography is the *Photo Crop Calendar*. A photo crop calendar is a temporal description of the condition and state of development of specific crops found within a region. The characteristics used to describe the crop's development are those that most closely relate to its photo image, namely, relative age development (such as seeded, young, mature, dry), percentage of canopy cover, and height. These characteristics change throughout the growth cycle of a developing crop, and thus the photo image of the field in which the crop is planted also changes.

Key stages in the development of cotton are illustrated in Figure 3. The ground photos were taken during the 1970 growing season and represent the average development of the crop throughout the county for that year. Field preparation began in February and planting did not get underway until late in March so that through most of March fields to be cotton were in a bare soil state (Figure 3A). By May much of the crop had emerged and canopy cover varied from zero percent to 5 percent with most plants less than 4 inches tall (Figure 3B). This stage of development still imaged as bare soil on the high-altitude aircraft photograph. In July and through August and September the canopy cover was at its maximum development in any given field, and throughout the county, canopy covers varied from 50 percent to 100 percent with most plants at least 2 feet tall (Figure 3C). Defoliation in preparation for harvest and harvesting operations were well underway by October with most of the crop having been picked by the end of November. Canopy cover decreases to as little as 20 percent after defoliation and harvest so that the photo image of cotton fields was variable after defoliation began (Figure 3D).

A simplified crop calendar for all the major crops in Maricopa County is reproduced in Figure 4. In this diagram the minus (−) line represents essentially a bare soil or minimum vegetation signature for the fields in which the crop is planted or to be planted. The plus

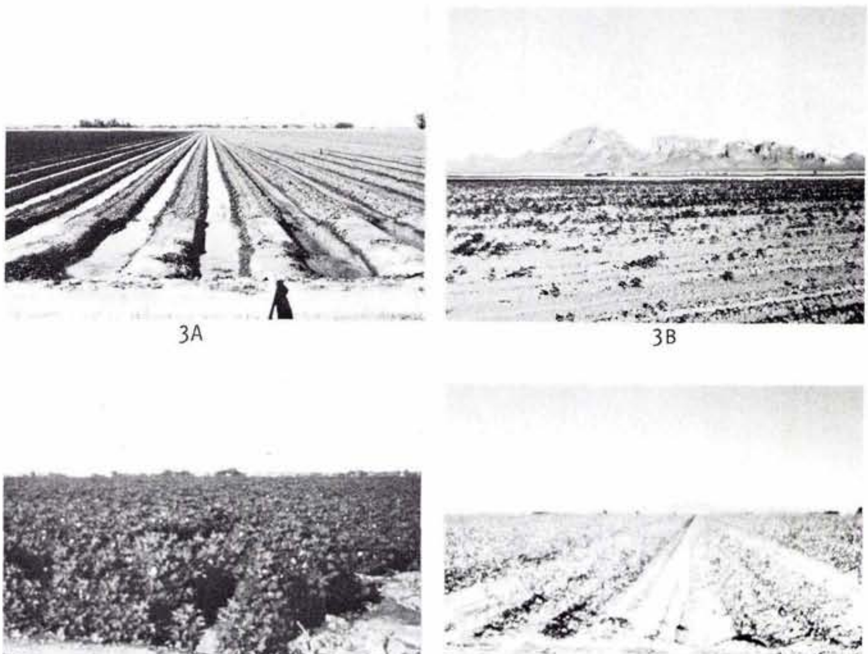


FIG. 3. Key stages in the development of cotton. These photos were taken during the 1970 growing season and represent the average development of the crop throughout Maricopa County for that year. (*3A*). Bare soil field which has been prepared for the planting of cotton in March. (*3B*). Young cotton plants have emerged but canopy cover is less than 5 percent. Such a field would appear as a bare soil field on high-altitude aircraft photographs. (*3C*). Maximum plant canopy development in mid-summer appears as a definitely vegetated field on high-altitude aircraft photographs. (*3D*). Defoliant has been applied in the early fall in preparation for harvest. Canopy cover decreases and the fields appearance on high-altitude aircraft photographs are variable.

(+) line represents the maximum vegetation stage of the crop at its maximum canopy cover and the maximum uniformity of development of the crop throughout the region. Sloping sections of the curves represent less than maximum canopy cover plus variability within the crop as a whole. That is, although *some* fields may display maximum canopy cover or crop development, other fields of the same crop are at lesser stages of development and as a whole the crop's photo characteristics are quite variable from field to field.

Ideally the best dates on which to sample are on those that are the least variable in terms of growth condition for the specific crop of interest, and on those for which the crop of interest would return the maximum difference in signature from other crops also presents. By reference to the crop calendar for cotton, one can see that these conditions are best fulfilled by a combination of May-July, May-August, and May-September photography. In May the cotton fields with less than 5 percent canopy cover possess a bare-soil signature on high-altitude aircraft photographs. At this time cotton may best be separated from alfalfa, sugar beets, safflower, and the small grains. There is possible confusion, however, of cotton with sorghum and fallow fields. In July, cotton fields can be distinguished from fallow fields because cotton fields now possess their maximum canopy cover whereas fallow fields are still bare. From the crop calendar it does not seem possible to separate consistently cotton from sorghum in any of the months because the two crops have such similar crop calendars.

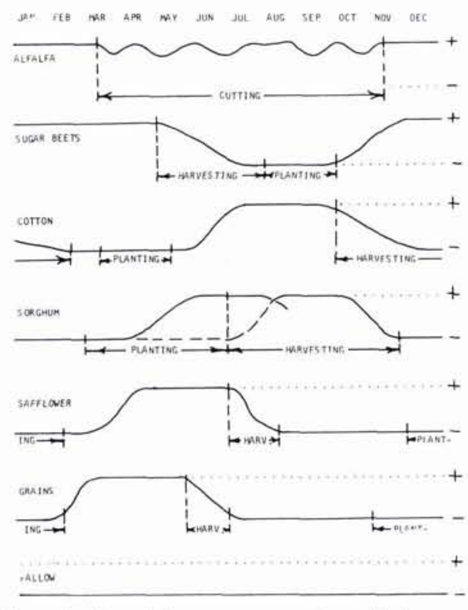


FIG. 4. Graphic representation of the crop calendars of the major crops in Maricopa County, Arizona. In the diagram the minus (−) line represents essentially a bare soil or minimum vegetation signature for the fields in which the specific crop is planted. The plus (+) line represents the maximum uniformity of development of the crop throughout the county. Sloping sections of the curves represent less than maximum canopy cover plus variability within the crop as a whole. That is, although *some* fields may display maximum canopy cover or crop development, other fields of the same crop are at lesser stages of development and as a whole the crop's photo characteristics are quite variable.

To test the effectiveness of the above predicted combination of dates for an inventory, a series of preliminary tests were performed. These preliminary tests were designed to determine the best type of photography (color or false-color infrared) as well as the best combination of dates to be used for identifying cotton. The May-August and May-September combinations could not be tested as August and September photography was not available. However, combinations of months May-June, May-July, May-October, June-July, June-October, and July-October were presented to 12 interpreters in both color and false-color infrared, 9 × 9-inches format, 1:120,000-scale photographs. Interpreters were trained on one set of the ground-data cells and tested on another set. They were asked to indicate only the cotton fields. After interpretation of the combination of two months, an interpreter was given back his original two months of photography with the addition of a third month on the same kind of photography, and asked to reinterpret the same areas that he had done previously. This second test was to see if any significant increase in accuracy or decrease in commission error could be achieved with the addition of the third month. Three-month combinations included: May-June-July, May-June-October, May-July-October, and June-July-October, again in both types of multiband photography, i.e., color and false-color infrared.

The results for these preliminary tests are shown in Table 2. These tests were undertaken to determine the best multiband photography (color or false-color infrared) as well as the best combination of dates of photography to be used in an operational inventory for cotton. The results are expressed in both percent correct and percent commission error which were calculated using the formulas:

$$\textit{Percent correct} = (A/B) \times 100$$
$$\textit{Percent commission} = C/D \times 100$$

where A is the acreage of correctly interpreted fields, B is the total acreage of cotton fields present, C is the acreage of incorrectly interpreted fields, and D is the total acreage of fields interpreted as cotton fields by the interpreter. A one-way analysis of variance (ANOVA) of these results showed that differences between percent correct and percent commission error values were not statistically significant at the 5 percent level.

Although the differences between percent correct and percent commission error values for the different combinations of months and types of photography are not statistically significant, these values lend support to the predicted combination of dates from the photo crop calendar. Results for combinations of three months of photography (not shown) indicated that the addition of the third month did not significantly contribute to greater accuracy, and, in some instances, the addition of the third month seemed to tax and frustrate the interpreters. Consequently, based on these test results, the cotton inventory for Maricopa County was completed using the May and July color photography in concert. The color photography seemed to give slightly better results than the false-color infrared for crop identification purposes, whereas false-color infrared seems better suited to the study of crop stress conditions.

PERFORMING A CROP INVENTORY

The cotton inventory was designed not only to test the sequential technique but also to compare results obtained from two different formats and scales of high-altitude aircraft photographs, namely, a 9 × 9-inches format at a scale of 1:120,000 and a 70-mm format at a scale of 1:450,000. The country was divided into three areas roughly equal in the number of cropland acres and a different interpreter was assigned to each area. Each interpreter used only one scale and format of photography, i.e., 9 × 9-inches, 1:120,000-scale photographs or 70-mm, 1:450,000-scale photographs, so that six interpreters took part in the experiment.

TABLE 2. RESULTS OF THE PRELIMINARY TESTS ON THE COMBINATION OF TWO MONTHS OF PHOTOGRAPHY.

Date/Type	*Percent Correct*	*Dates/Type*	*Percent Commission Error*
MayJuly-Color	99.35	MayOct-CIR	4.15
MayJuly-CIR	98.02	MayJune-CIR	5.02
MayJune-CIR	94.83	MayJune-Color	5.95
MayJune-Color	93.67	MayJuly-Color	9.23
MayOct-Color	92.50	JuneJuly-CIR	12.63
JuneJuly-CIR	90.47	MayJuly-CIR	13.03
JuneOct-CIR	84.73	MayOct-Color	14.88
JuneOct-Color	84.22	JuneJuly-Color	15.15
MayOct-CIR	74.82	JulyOct-CIR	18.52
JulyOct-CIR	74.62	JuneOct-Color	20.37
JulyOct-Color	71.62	JuneOct-CIR	23.57
JuneJuly-Color	70.23	JulyOct-Color	26.33

All interpreters, except one, were highly skilled and had extensive experience in the use of high-altitude aircraft photographs. The one exception, though skilled, lacked the same amount of experience as the rest of the interpreters. Four to five training cells were given to each interpreter so that each could train himself to recognize the image characteristics of cotton on the particular photography that he would use in the inventory. These training cells consisted of four-square mile plots for which ground data had been collected at the time of the overflights in May and July. Figure 5 shows an example of one of the ground data training cells in both May and July. The fields indicated in the photos were young cotton fields in May, but due to the low percentage of canopy cover, these fields appear as bare soil fields on the May color photography. The July photography, however, clearly displays a well-developed vegetated field. This pattern of negative in May and positive in July was the criteria used by the interpreters to identify cotton fields.

The county was inventoried section by section for almost all of the cropland area within the county (approximately five percent of the cropland lacked adequate photo coverage to be included within the survey). Interpreters using the 9 × 9-inches format were asked to mark onto overlays of the July photography, the fields that they had interpreted as cotton fields. They were not asked to estimate the acreage of these fields as this could be done later by another person, thus minimizing the time spent on the inventory by the experienced interpreters. Similarly the interpreters using the 70-mm format were asked to mark their interpreted cotton fields onto enlarged black-and-white prints as the 70-mm photography did not allow adequate space for annotation. Equipment used in the inventory, other than the photography already described consisted of a light table for viewing the photography and an 8× magnifier.

After the interpretation phase of the inventory was completed, the interpreters presented their interpretations to the preson who would estimate the acreages. The acreage estimations were made by eye with the aid of an area template. For the 9 × 9-inches format (1:120,000 scale), a template with a minimum area designation of ten acres was

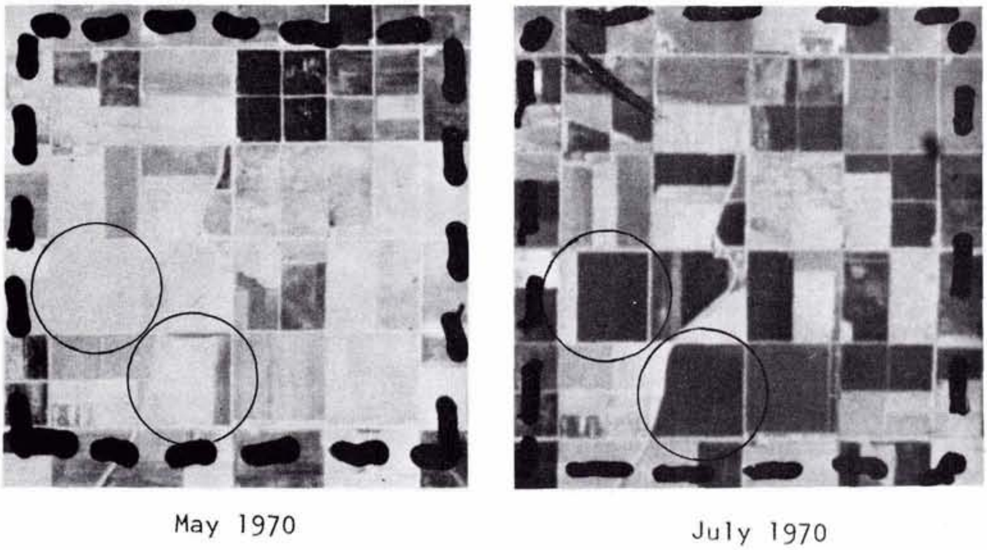


FIG. 5. Black-and-white copies of high-altitude color photographs taken in both May and July of 1970 of one of the ground data training cells. Selected cotton fields have been circled to illustrate their *bare soil* apperance on the May photograph due to less than 5 percent canopy cover, and their densely vegetated appearance on the July photograph due to greater than 50 percent canopy cover. These characteristics were used by the interpreters to identify cotton fields from all other crop types present.

applied directly to the positive transparency and viewed on the light table. The acreages of the interpreted cotton fields were summed by square-mile sections. For the 70-mm format (1:450,000 scale), positive transparencies were placed in a microfiche reader and enlarged on its rear projection screen approximately 30×. A template with a minimum area designation of 2.5 acres was then applied to the enlarged image and the acreage of the interpreted fields was again summed by square-mile sections. Regression estimators were used to adjust the acreage estimates for the individual areas and a sampling error was calculated for each of the individual areas. The overall county estimate was calculated by treating each of the three areas as an individual stratum (Draeger, Pettinger and Benson, 1971).

RESULTS OF A CROP INVENTORY

Results of the cotton inventories performed on the 9 × 9-inches format, 1:120,000-scale photographs and the 70-mm format, 1:450,000-scale photographs are presented in Table 3. Interpretation times for each interpreter were recorded separately from the acreage estimation times so that a separate evaluation could be made of the two phases of the inventory technique, i.e., crop identification and acreage estimation. Sampling errors and ratio correction factors as well as a percent correct and a percent commission error figure are also presented for each interpreter. The percent correct and percent commission error figures were obtained by a field by field analysis of the interpreters' performance within the ground data cells distributed throughout the inventoried area. The percentage of the total error which was due to the template estimation of acreages is also presented for each area for both sets of photography. The total error in this part of the evaluation was defined as the omitted acreage plus the committed acreage plus the acreage error due to template evaluation of the acreages.

Sampling error is a percentage figure relating the standard deviation of the estimated acreage to the magnitude of the total estimated acreage. It was calculated using the formula: Sampling error equals (standard deviation of the estimated acreage $S\hat{Y}$ divided by estimated acreage $\hat{Y}$) times 100. Ratio correction factors for each interpreter indicated whether an interpreter over- or underestimated the cotton acreage. A ratio of greater than 1 indicates that the acreage was underestimated whereas a ratio of less than 1 indicates that the acreage was overestimated. The USDA Statistical Reporting Service's estimage of the cotton acreage for 1970 in Maricopa County has also been presented for comparison with the inventory results. For a more detailed description of the

TABLE 3. RESULTS OF THE 1970 COTTON INVENTORY.

Interpreter Area	Interpretation Time (Hrs.)		Acreage Estimation Time (Hrs.)		Sampling Error (%)		Ratio Correction Factor		Interpreter % Correct % Commission		% of Total Error Due to Acreage Estimation	
	9×9	70mm	9×9	70mm	9×9	70mm	9×9	70mm	9×9	70mm	9×9	70mm
1	8.5	11.8	4.1	19.0	6.8	15.6	1 09	.61	92.6 7.6	98.8 43.2	28.9	6.2
2	8.0	19.0	2.6	6.4	20.8	22.1	.94	.88	98.8 12.4	97.7 24.4	38.5	20.4
3	12.0	13.2	3.8	9.1	21.4	33.5	1.00	1.36	97.5 11.5	75.6 18.6	36.7	4.1
Total Area	28.5	44.0	10.5	34.5	9.4	15.6			96.3 10.5	92.0 28.7	34.7	10.2

Total Inventory Time (Hrs.)		Total Estimated Acreage (Acres)		
9×9	70mm	9×9	70mm	SRS
39.0	78.5	107,111	111,945	99,500

statistical procedures used, see *Elementary Forest Sampling* by Frank Freese, Agriculture Handbook No. 232, U. S. Department of Agriculture, Dec. 1962.

Total time required for the inventory using the 9 × 9-inches format was 39 hours with a total sampling error of 9.4 percent. The total time required for the inventory using the 70-mm format was 78.5 hours with a total sampling error of 15.6 percent. The greater time required in the use of the 70-mm photographs was due to more difficulty and greater inconvenience involved in handling the smaller scale and format. The fact that the interpretation could not be directly recorded on the 70-mm photographs as in the case of the 9 × 9-inches format, but had to be transferred to enlarged prints, also added to the difficulty of working with the 70-mm photographs.

The greater sampling error associated with the 70-mm photographs can be explained by examining the percent correct and the percent commission error figures for the individual interpreters. The interpreters as a whole achieved quite high percent correct figures, but interpreters using the 9 × 9-inches format rather than the 70-mm format photographs had only half the commission error that interpreters using the 70-mm photographs did. In the interpretation of the 9 × 9-inches format, sorghum accounted for 72 percent of the commission error, citrus trees for 3 percent, alfalfa for 3 percent and other crop types for 22 percent. In the interpretaton of the 70-mm photographs, sorghum accounted for only 48 percent of the commission error, alfalfa for 23 percent, citrus trees for 10 percent, and other crop types for 19 percent. One of the factors influencing the greater commission error in the interpretation of the 70-mm photographs was the more yellow cast of the May 70-mm photographs as compared to the May 9 × 9-inches photographs. The yellow cast obscured some of the vegetation tones such that fields that normally would appear vegetated appeared as bare-soil fields which was the proper appearance of cotton fields at this time of the year. Another factor contributing to the higher commission error was the loss of textural information on the smaller scaled 70-mm photographs as compared to the larger scaled 9 × 9-inches photographs. The greater textural information contained on the 9 × 9-inches photographs probably aided the interpreters in eliminating some fields as possible cotton fields.

The proportion of total error due to template estimation of the acreages was 35 percent in the case of the 9 × 9-inches format and 10 percent in the case of the 70-mm format. These percentages were arrived at with the use of scanner data in which the planted area of fields within the ground data cells was scanned on the 70-mm photographs providing accurate acreage information for these fields. These scanned acreages were then compared with the template estimates and the total difference was calculated. This difference was then divided by the total error as defined above. The nature of the error due to the use of a template for acreage estimation was of the same nature and magnitude for both scales and formats of photographs so that the differences in the percentages of the error due to this factor can be explained by the decrease in the interpretability of the 70-mm photographs.

Despite the differences in sampling errors between the different scales of photography, both of the sampling errors (9.4 percent for the 9 × 9-inches format, and 15.6 percent for the 70-mm format) are within the estimated sampling errors at the county level that the Statistical Reporting Service considers it is achieving in its enumerative surveys, i.e., between 10 percent and 20 percent. Thus either scale and format or photography would produce data that are compatible with present accuracy levels in agricultural statistical sampling systems. However, the greater ease of handling and the lesser amount of time required to work with the 9 × 9-inches photographs would indicate that if a choice were to be made between the two types, the 9 × 9-inches, 1:120,000-scale imagery would be preferred.

The cotton inventory was the second inventory performed for the purpose of determining the acreage of a specific crop. The first inventory was performed for the 1970 wheat and barley crop in Maricopa County using basically the same sequential technique, and was reported upon by Draeger, Pettinger, and Benson (1971). A comparison of the results of the wheat-barley inventory with those of the cotton inventory (Table 4) shows that the sampling errors are similâr. This would indicate that the sequential technique used with high altitude aircraft photography could be applied to the inventory of other crop types with similarly expected degrees of accuracy.

In Table 4, basically the same sequential technique was applied to the inventory of both crop types. The similarity of the sampling errors would tend to indicate that comparable degrees of success could be expected using the sequential technique and high-altitude aircraft photographs for inventorying other crop types.

Summary and Conclusions

Agricultural sampling as conducted by the U. S. D. A. Statistical Reporting Service relies in part on a stratification of general land use as a method of increasing the efficiency of the subsequent sample. Such stratifications are performed on conventional aerial photographs and can be up to eight years out-of-date. The number of conventional aerial photographs required to cover a state the size of California is so immense that the cost and time involved in acquisition and analysis makes such stratification tasks impossible to perform on a yearly basis using the percent system. Changes occurring in land use which could affect sampling accuracy are often missed and not incorporated into the sampling scheme until the next full update of the stratification which occurs about every eight years. The errors associated with the use of out-of-date stratifications are accepted as part of the sampling error of the present system.

From the stratification studies using the ERTS-1 imagery of San Joaquin County, California, it was shown that satellite imagery of the quality of ERTS-1 can offer a feasible solution to the problem of out-of-date stratifications. In the San Joaquin County example 901,000 acres (approximately one eighth of an ERTS-1 frame) were stratified in less than 45 minutes. As one frame of satellite imagery covers 100 miles square, the use of such imagery can greatly reduce the amount of time required for stratification tasks. Satellite imagery can serve as a quick and convenient check between regular stratifications, thus allowing recent changes to be incorporated into the present year's sampling program. The ability to monitor and incorporate recent changes into a sampling program should increase the accuracy of such sampling systems.

Inventory techniques for specific crops using high-altitude aircraft photographs have also been developed and tested. An inventory for the 1970 cotton crop in Maricopa County, Arizona was conducted testing two formats and scales of high-altitude aircraft photographs, i.e., 9 × 9-inches format, 1:120,000-scale color photographs and 70-mm format 1:450,000 scale color photographs. By use of a sequential technique it is possible to distinguish successfully specific crops from one another with accuracies that are comparable to presently operating inven-

Table 4. Comparison of Results from the Small Grains Inventory with Those of the Cotton Inventory Using 9 ×9-Inches Format, 1:120,000-Scale High-Altitude Color Photography.

Crop Type	*Interpretation & Preparation Time*	*Sampling Error*	*Estimated Acreage*
Barley		11%	50,044 acres
Wheat	90.0 hours	13%	41,714 acres
B/W Combined		8%	92,207 acres
Cotton	52.8 hours*	9%	107,111 acres

*Includes 13.8 hours of materials preparation time.

tory systems. The sequential technique is based on the fact that different crops pass through their various phenological stages at different times. By using the temporal patterns of phenological change of a certain crop as observed on two or more dates of photography, it is possible to identify specific crops.

Using a combination of May and July color photographs on both formats and scales of high-altitude aircraft photographs, sampling errors of 9.4 percent for the 9 × 9-inches format, 1:120,000 scale and 15.6 percent for the 70-mm format, 1:450,000 scale were obtained. Both of these sampling errors are compatible with accuracy levels that the Statistical Reporting Service believes it is achieving at the county level. However, the 9 × 9-inches format had a lower sampling error and took only half the time required for the 70-mm photographs. It was concluded from these studies that satellite and high-altitude aircraft imagery could be used effectively for the gathering of agricultural statistical data. Data gathered by these remote-sensing systems was as accurate as, and could be more timely than, data gathered by presently operating sampling systems. It is hoped that such techniques as described above can be included in present data-gathering systems to increase their accuracy and timeliness, and to decrease the amount of effort involved in the gathering of agricultural statistical data.

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