VIDYA REPORT NO. 118
December 13, 1963

DEVELOPMENT OF LIVESTOCK AND CROP SURVEY TECHNIQUES
Phase I

by
Carl H. Strandberg
Callie Lukermann

prepared for
U. S. Department of Agriculture
Statistical Reporting Service

USDA Order No. D/A 12-18-0018-60

VIDYA PROJECT NO. 8290

VIDYA

RESEARCH AND DEVELOPMENT

1450 PAGE MILL ROAD, PALO ALTO, CALIFORNIA

A DIVISION OF Itek CORPORATION

FOREWORD

Under USDA Contract No. 12-18-0018-60 dated May 13, 1963, the Vidya Division of Itek Corporation has conducted Phase I of a program on the development of livestock and crop survey techniques. The program has been carried out on behalf of the Statistical Reporting Service, U. S. Department of Agriculture. Phase I has been a feasibility study, devoted to ascertaining the conditions under which livestock and crops can be reliably identified from aerial panoramic photography.

The final report on Phase I summarizes the work done by Vidya under the contract. It gives Vidya's conclusions as to the feasibility of crop and livestock surveys, and recommends procedures to be followed in the further development of survey techniques.

ABSTRACT

This report describes the work done for the Statistical Reporting Service, U. S. Department of Agriculture, under USDA Contract No. 12-18-0018-60, in Phase I of a program devoted to the development of livestock and crop survey techniques. The report discusses the feasibility of detecting and identifying livestock, row crops, and grain crops on aerial panoramic photography.

In view of the extremely high ground resolutions required to make such identifications, Vidya's HyAc ("high acuity") aerial panoramic camera was used to take the experimental photography for Phase I. With the HyAc camera and suitable aerial film-filter combinations, exceptionally good interpretability can be obtained. Phase I included trial flights for determination of photographic specifications, and simulated operational flights over areas selected by the Department of Agriculture. The simulated operational flights were made at altitudes of 5,000 to 14,000 feet above the ground with Eastman Kodak SO-226 film and Wratten 21 filter.

The HyAc photography was interpreted in the Vidya Image Analysis Center. Direct viewing microscopes and rear-projection viewers magnifying up to 20 times were used in the interpretation. The initial interpretation was later re-analyzed, interpretation procedures and photographic images were appraised, and many improvements were made in the initial interpretation system. This reanalysis included comparative evaluation of negatives and positive transparencies, and a critical evaluation of photographic criteria for:

(1) Identifying and counting livestock (cattle and sheep, including calf and lamb crop).

(2) Identifying grain crops (wheat, barley, oats) and row crops (sorghums, corn, dry edible beans, sugar beets); acreage determination in each category.

This report emphasizes the results obtained in the study of livestock. Efforts in grain and row-crop identification, which requires more detailed study of tone, texture, row spacing, and other characteristics, were devoted to the development of criteria which offer the greatest potential for crop identification.

The Vidya Spectroterrometer was used for trial field measurements of the spectral reflectance. These measurements are to be used for:

(1) Determination of optimum film-filter combinations for the identification.

(2) Utilization of Vidya's color-enhancement techniques for rapid analysis.

It is felt that this work is applicable in Phase II crop identification.

Analyses were also made of both negative and positive images of livestock and crops in photographs taken with Vidya's nine-lens multiband camera.

Additional background research was done on:

(1) Aerial camera systems for livestock and crop surveys.

(2) Film-filter combinations for livestock and crop surveys.

(3) Aerial flight mission planning.

(4) Photographic interpretation keys.

(5) Ground and airborne spectral reconnaissance as an aid to livestock and crop surveys.

These subjects have been included as appendices to this report, at the request of the Department of Agriculture project officer.

At the end of Phase I of the program, Vidya has concluded that:

(1) Aerial photographic livestock surveys are feasible, when cameras which yield extremely high ground resolution are used with film-filter combinations which yield the greatest possible range of distinguishable gray tones in the photography.

(2) Additional development work, including ground and aerial spectral reconnaissance to optimize film-filter selection, is needed for crop identification.

(3) Photographic interpretation keys should be developed for use in livestock and crop surveys.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES TO APPENDICES

DEVELOPMENT OF LIVESTOCK AND CROP SURVEY TECHNIQUES

1. INTRODUCTION

This report describes the work done under Phase I of a three-phase program of research on techniques for conducting aerial photographic surveys of livestock and agricultural crops. As stated in Itek Proposal No. 3603, Phase I was planned as a feasibility study, devoted to ascertaining the conditions under which livestock and crops can be reliabily identified from aerial panoramic photography. Phase II will extend the results obtained in Phase I and will be devoted mainly to establishing a statistical confidence level for livestock and crop identification. It may also include sample identification keys to livestock and crops in a limited region. Phase III will consist of a trial operational survey, including an actual inventory of crops and livestock in a small controlled area.

The aerial photography for Phase I was obtained with Itek's HyAc panoramic camera. Test photography was first flown over the area of Milpitas, California; then, on a simulated operational basis, areas designated by the Department of Agriculture in Utah, Colorado, and Wyoming were photographed. Most of the photography was taken at scales from 1:11,000 to 1:14,000; selected areas were photographed at larger scales.

In interpreting the "operational" photography, attempts were made to count livestock and to classify them as to use, age, sex, and (as an aid to establishing use) breed. Wherever possible, this work was checked against sample counts made on the ground by Department of Agriculture field personnel. The correlations between photointerpretation and ground data were criticized from the point of view of statistical validity, which will be the principal criterion of photointerpretation in Phase II.

Representative grain and row crops identified on the ground by Department of Agriculture personnel were scrutinized on the photographs in order to judge the reliability of crop identifications made on HyAc photography taken early in the growing season. Possible criteria for crop identification were reviewed according to their usefulness in an aerial panoramic survey system.

The photographic specifications and image quality of the Phase I photography were analyzed, and experiments were made with alternative films, filters, and processing methods. Multiband photography of the Milpitas area, obtained by Vidya under Project VELA, was studied for interpretability in the various spectral bands.

2. METHODS OF PROCEDURE

2.1 Preparations for Flights

During May 1963, in cooperation with the Department of Agriculture and Mr. Robin Welch, Vidya consultant, plans were made for a local test flight and for simulated operational coverage in Utah, Colorado, and Wyoming. The areas to be covered in the operational flights were chosen, and the desired flight lines drawn on maps, by the Department of Agriculture. Photographic area coverage was delineated on the flight maps by Vidya, and copies of the annotated maps were forwarded to Department of Agriculture field personnel.

2.2 Local Test Flight

On June 5 a local test flight was made near Milpitas, California. This flight is described in the first interim progress report. The flight line extended about 6 miles along Route 9 between Lawrence Station Road and a point just east of the Route 17 freeway. Passes were made at 5,000, 10,000, 15,000, and 20,000 feet, once in early afternoon and once in late afternoon. The Milpitas area being near sea level, these altitudes gave approximate contact photo scales of 1:5,000, 1:10,000, 1:15,000, and 1:20,000 along the flight line.[1] Eastman Kodak SO-226 film and Wratten 21 light-red filter were used at 1/300-second exposure.

2.3 Trial Interpretation

Trial cattle counts were made in selected areas at the four photo scales, using Vidya's rear-projection viewers, Bausch & Lomb Stereozoom microscopes, and light tables. Film densities were studied, and tone contrasts between cattle of various colors and their background were noted.

The trial interpretation indicated that both cattle and sheep could be detected in aerial panoramic photographs at scales as small as 1:20,000. However, some changes in photographic specifications were recommended for the simulated operational photography. The specifications were:

---

[1] Photographic scale is calculated from camera focal length and altitude above GROUND LEVEL. The HyAc camera, having a 12-inch focal length, gives a photo scale of 1:20,000 when exposed at 20,000 feet above ground. Because of the increasing obliquity at the sides of the panoramic sweep, photo scale becomes slightly smaller away from the flight line.

2.3.1 Time of day

The early afternoon photography, though excellent in itself, did not provide animal shadows of sufficient visibility. Moreover, animals seek shade in the middle of the day, and many were probably hidden from view in the photographs. The late afternoon photography, though it provided a better light angle for shadow interpretation, gave poorer image contrast, owing to increasing atmospheric haze. The operational photography was therefore scheduled between 8:00 and 11:00 a.m., in order to combine the advantages of clear atmosphere, optimum light angle for interpretable shadows, and visibility of animals in the open during the cool of the day.

2.3.2 Scale and scan angle

The smallest test scale, 1:20,000, was eliminated. Although cattle were detectable in the 1:20,000 Milpitas photographs, some were probably overlooked, and reliable age and sex distinctions were not possible. It was therefore decided to take most of the operational photography at about 12,000 feet above ground level, giving a photo scale of 1:12,000, with some passes at 5,000 to 6,000 feet above ground over areas selected by the Department of Agriculture for more detailed study. Three of the Wyoming flights were planned for 20,000 feet above sea level or 12,000 to 14,000 feet above ground. The camera scan angle was set at 90° (45° either side of nadir) to ensure usable imagery throughout the panoramic strip.

2.3.3 Film and filter

As in the Milpitas test flight, SO-226 film and Wratten 21 light-red filter were used for the operational photography. This is a combination which has given excellent results with agricultural surveys in California, when very small objects of varying tones must be detected against a variety of backgrounds. As will be seen later, however, it appears that insufficient allowance was made for the different atmospheric conditions in the High Plains.

2.4 Simulated Operational Flights

On June 9, 10, 11, and 12, after consultations with Department of Agriculture representatives, 27 passes were made over 11 flight lines in Utah, Colorado, and Wyoming (Figs. 1 and 2). Details of these flight lines are given in the mission log, pages 36 and 37. The photographic flight lines for the 1:12,000 coverage totaled 190 miles, and the total flight path, including transit mileage between flight lines, was well over the 250-mile maximum stated in Proposal No. 3603. The total area coverage of the photography was nearly 700 square miles, again much more than the proposal stated.[2]

The low-altitude photography was to have been obtained on instructions from the Department of Agriculture. Unfortunately no information on the areas of greatest interest in Colorado was received from the Department before flight time, and the low-altitude passes in Colorado had to be made by visual selection from the air. The areas to be photographed in Utah were changed by the Department on June 7 and 8; the low- and high-altitude passes were made on the same flight lines. Low-altitude flights were made in Wyoming west of Laramie and over the Wyoming Hereford Ranch east of Cheyenne.

For the reasons given above, most of the operational photography was flown between 8:00 and 10:00 a.m. Some of the flight lines, however, had to be flown within 2 hours of noon in order to complete the mission in the required time.

On the same days that the photography was flown, staff members of the Department of Agriculture went into the field to count livestock and identify crops in selected ground areas.

The photographs were immediately processed and numbered. The film was developed to a very high gamma[3] in order to achieve the highest possible contrast. These efforts seem to have been somewhat overdone; the operational photography would have been more interpretable if less contrast had been used.

Film exposed in Wyoming, Colorado, and Utah was processed in an Oscar Fisher G-6 processor. Film was processed at 3 and 4 feet per minute, 85° F. Film gamma varied from 2.95 to 3.03. D-19 developer was used.

Subsequently, experiments have been conducted with SO-226 film to reduce contrast levels. Levels have now been brought down as low as (gamma) 1.27, using D-76 developer. All of the subsequent development work has been conducted in the laboratory using standard

---

[2]Proposal No. 3603 and the work statement both specify "a flight line in the Wyoming-Colorado area of approximately 250 miles total." The proposal further states "the photography will cover an area not to exceed 300 square miles." These limits were exceeded when the Department of Agriculture chose several short flight lines instead of one, and added three in Utah.

[3]Curve expressing photographic tone contrast, or difference between highest and lowest density in a given negative.

sensitometric techniques. No SO-226 film exposed from the air has been processed to lower gammas, that is, to yield a longer gray scale.

The positive transparencies made for interpretation of selected areas were printed to reduce contrast, with improved results. Duplicate positive transparencies were made and forwarded to the Department of Agriculture. The ground data sheets prepared by the Department field men were received, and prints were made of the photographs which accompanied the ground data.

2.5 Experimental Livestock Counts

During July and August Vidya's large screen rear-projection viewers were being modified and reassembled, and were not available for use in the project until late August. An intensive analysis of passes 1 to 10, covering flight lines 1, 2, and 3 in Utah and D, E, and G in Wyoming and Colorado, was then made. Livestock were counted in several hundred areas, including dairy feed lots and pastures, family-type barnyards, and range areas, on a total of 376 exposures. The counts were made "cold", without reference to the ground data collected by the Department of Agriculture. The animals counted were tabulated by type, breed, sex, age, and environment; all areas where counts were made were marked on positive prints for quick recovery in review and evaluation. Problems in interpretation were noted, and typical and atypical areas were selected for further study in the compilation of key materials.

The greatest difficulty in making livestock counts was the high contrast of the photography; dark-toned areas were very dark and light areas very bright, with little range of gray tones between. Accurate counts were difficult or impossible in many areas of low film density (very light areas in the projected negatives), where the tone of the background approximated that of the animals, and animal shadows were barely visible. This problem occurred in the large-scale photography of passes 4 to 6 as well as in the small-scale passes, though all livestock should have been detectable even on the smaller-scale photographs.

At least two factors, in addition to the high gamma used in processing, contributed to the excessive contrast of the operational photography. First, all of the high-resolution aerial films recently developed for medium- and high-altitude work have high contrast, a normal requirement for cultural and military photo analysis. Up to now most of Vidya's work with the HyAc camera has been directed toward increasing contrast. In this project, however, the animals to be detected are many different colors and are seen against many types of background - the trampled earth of feed lots, cultivated pasture, range grass, and brush. For a livestock survey we therefore need, not the extremes of contrast, but the greatest possible range of distinguishable gray tones (gray scale) in the photographs. Second, atmospheric haze, which adds non-image-forming blue light to the scene and tends to "gray out" the photograph (reduce the contrast), is low in mountain and plateau areas where the atmosphere is thin. Early in the morning the haze level is particularly low. A low level of atmospheric haze will be considered in any Phase II photography flown early in the day over areas of medium to high elevation. When photographing such areas, it appears desirable to include the blue-green part of the spectrum instead of blocking out this part with yellow or red filters as is normally done with aerial photography. During Phase II, multiband research will be undertaken to confirm this conclusion.

Another possible reason for the difficulties experienced in making the livestock counts was that light reflectance from the ground may have been low in part or all of the survey area at the time of photography. Meteorological data obtained from Fort Collins, Colorado, indicate that moderate to heavy rains fell throughout the state on June 9 and 10 and that evaporation rates were low during the next 2 days. The soil, therefore, must have been still damp on June 12 when the Colorado photography was taken. Moisture reduces the light reflectance of bare soil, thus darkening the soil tone in aerial photography and reducing the tone contrast between dark-colored animals and their background. Moisture also reduces the reflectance of dead vegetation, but usually increases that of live vegetation.

In making the livestock counts, a process which consumed most of project time from August 20 to September 28, strenuous efforts were made to discover means of identifying breeds of cattle, in addition to age class and sex. The Department of Agriculture does not require breed identification as a specific objective in this project but is rather interested in use classes (beef and dairy) and age class (calf crop) of cattle, and in age class (lamb crop) of sheep. This simplifies the counting problem insofar as use classes can be distinguished by association, that is, by such clues as the location of cattle, in small pastures close to dairies or on the open range; the presence or absence of permanent feed troughs, cooling sheds for milk, supplementary feed strewn in fattening pastures, loading corrals and chutes; and other indications of use, apart from the appearance of the animals themselves.

However, the frequency of mixed herds in the Phase I photography indicates that such associations will fail often enough to introduce significant errors into the count. Breed identification will be desirable, and in some regions necessary, for the truly operational inventory of Phase III. For example, it will be necessary to distinguish black or nearly black Holstein (dairy) from Black Angus (beef), or brown Ayrshire and Brown Swiss (dairy) from brown Hereford (beef), when they are seen in similar environments or in mixed herds. However, it should not be necessary to distinguish light-brown Guernseys from light-brown Jerseys, since both are dairy cattle. The number of breeds which must be identified for a reliable count of use classes will, of course, vary with the size of the region being surveyed; if certain breeds do not appear in, say, the High Plains, then they need not be keyed out for a survey of that region.

Livestock counts were also made on pass 13, covering flight line 2 in Colorado at the scale of 1:11,500. Counting in this pass was restricted to the areas sampled on the ground by the Department of Agriculture. So far as possible, age and breed identifications were checked against the ground data while the counts were being made. Pass 13 was then compared with passes 14 to 18, flown along the same flight line at the scale of 1:5,500, in order to judge the interpretability of animal images at the two scales. Unfortunately, none of the ground samples fell in the image area of the large-scale passes, so direct comparison of photo counts with ground counts could not be made.

2.6 Review and Evaluation

Efforts were next directed toward review and evaluation of the operational livestock counts, particularly toward checking the counts against those made on the ground and discovering the causes of discrepancies. Passes 2 and 5, covering flight line 2 south of Salt Lake City, were selected for first review, since the photo interpreter who made the original counts had found that pass 5 contained many good examples of livestock and environments to be studied for key compilation.

Pass 2 was flown at 16,400 feet above mean sea level. With average ground elevation of about 4,500 feet, this gives a flight altitude above ground of 11,900 feet and a photo scale of roughly 1:12,000 or 5-1/4 inches to the mile. Pass 5 was flown over the same area at 10,400 feet above mean sea level or 5,900 feet above ground; the photographs of this pass therefore have a scale of roughly 1:6,000 or 10-1/2 inches to the mile.

The first step in evaluating the photointerpretation was to make uncontrolled reference mosaics of both passes, and to plot on these mosaics the areas where livestock counts had been made on the ground by the Department of Agriculture. The photo counts on pass 2 were checked against the ground counts, and many areas were recounted (Table I). A positive transparency of pass 5 was made and projected opposite the negative for comparison of corresponding images. Images of cattle, horses, and sheep were closely examined at both scales and in both positive and negative, in order to judge the usefulness of shape, color (tone of gray in the photograph), shadow, and site as identification criteria for livestock. Images of cattle in the various spectral bands of the multiband Milpitas coverage were compared.

A similar check was made on flight line G, covering a range area east of Cheyenne, Wyoming. Pass 7 was flown on this line at an altitude above sea level of 18,200 feet. Ground elevation in the area varies from 5,000 to 6,000 feet, and the photo scale accordingly varies from 1:13,200 to 1:12,200. Pass 7 thus provides a good example of small photo scale, and a challenge to the photointerpreter to find cattle and sheep dispersed over large areas.

In evaluating the photointerpretation on pass 7, close attention was paid, not only to large herds and flocks on the range, but also to the sheep counts made on the ground at Archer Experimental Substation. Here small groups of sheep are kept in separate pens, giving an opportunity for controlled recounting and checking that does not exist on the open range.

In addition, the images seen on pass 7 were compared with those on the large-scale pass 8. Pass 8 was flown at 12,200 feet above sea level on a line roughly parallel to the Burlington & Quincy Railroad in the southwestern part of the image area of pass 7, including the Wyoming Hereford Ranch. No ground samples were taken in this area, but the photographs contain good representative images of cattle and horses in range environments.

The review of photointerpretation on pass 13 was accomplished mainly by recounting the same areas. This process showed that the head counts made in the initial interpretation were reproducible, that is, that they could be repeated to the same totals, but not that they were correct. For reasons explained in the next section, the correspondence between photo counts and ground counts on most of pass 13 is highly doubtful, and the correctness of the photointerpretation therefore unknown.

3. RESULTS OF LIVESTOCK SURVEY

3.1 Photo Scale

The statement made tentatively in the second interim report, that HyAc panoramic photography at scales of 1:5,000 to 1:6,000 is more than adequate for a livestock survey program, has been confirmed. The passes made in Phase I at these scales have been successfully used for detection and identification of animals by type, use class, age class, and, in many cases, breed. Such identifications can be made even without the aid of a key by persons with experience in photointerpretation or farming methods or both. Figures 19 to 23 illustrate the interpretability of animal images in large-scale HyAc photographs.

The second interim report further stated that a photo scale of 1:12,000 might prove satisfactory for operational surveys. In the light of subsequent review and re-interpretation, this suggestion now appears too optimistic.

It is true that correct head counts can often be made on photography at 1:12,000 or even smaller scale. Table II gives typical correlations between photo counts and field counts on the 1:12,000 to 1:13,000 photographs of pass 7. Although the photo scale is small and film density in many areas (including Archer Experimental Substation) too low, the photo counts on this pass compare favorably with the ground counts; and in at least one case, the 122 sheep found by the photointerpreter on exposure 207 where the field man only saw 90, the photo count is better.

Within the total head count, however, distinctions of age and breed, still less sex, are not consistently reliable at 1:12,000. Inaccuracies may occur when animals are closely bunched, so that their images in the photographs merge, or when they are dispersed so far apart that their relative size and shape cannot be judged. For example, if both heifers and mature cows appear in the same corral or pasture, they can usually be distinguished; if only heifers are present, they are likely to be mistaken for cows. Calves and lambs are distinguishable from adults, but they appear so small that many are missed. Beef and dairy cattle mixed in the same herd may be identified as all dairy, since at 1:12,000 the identification must be based more on environmental associations than on the body features of the animals.

For an operational survey the Department of Agriculture wishes to arrive at the smallest photo scale that will permit reliable identification and counting. Vidya recommends 1:7,000 to 1:8,000 as a minimum scale for the experimental photography of Phase II. This is only slightly smaller than the <u>largest</u> scale used in Phase I, and will provide images which are detailed enough for accurate counting without greatly increasing the expense of obtaining, processing, and handling the photographs.

Vidya has not abandoned efforts to bring photo scales of 1:12,000 and smaller into the range of usefulness for livestock surveys. It is entirely possible that such scales may become operationally feasible, once keys and other interpretation aids are developed and optimum photography obtained. Figure 3, an enlargement from the 1:13,000 photography of pass 10, illustrates the visibility of sheep and lambs at the smallest scales used in Phase I. If this degree of resolution and image contrast can be maintained over the entire region of an operational survey, then the small scale will be feasible.

3.2 Film, Filter, and Exposure

Comparative study of the multiband Milpitas photography, obtained by Vidya under Project VELA, suggests that the very high contrast of the Phase I HyAc photography should be modified to give better images of livestock, and perhaps also of crops. Figure 4 shows the six bands exposed in the visible spectrum for one frame of the Milpitas multiband coverage (the infrared bands were found less useful in this instance, and are omitted from the figure). Of this series, bands 3, 4, and 5, exposed in the middle visible part of the spectrum (500 to 650μ), seem to give the best tone contrasts for detecting and counting the cattle in the lower right part of the frame. Considering the need for relatively high subject-background differences, we conclude that the blue, blue-green, and red regions should be filtered out, leaving the green, yellow, and orange regions.

Vidya intends to make further studies of multiband photography before choosing a film and filter for the HyAc photography of Phase II. If possible, multiband photography will be obtained in the same area where experimental head counts are to be made in Phase II.

Exposure time will be accommodated to the width of the spectral band chosen for the HyAc photography, with allowance for the clear atmosphere of early morning in high-elevation areas.

3.3 Time of Year

Vidya assumes that photography for a livestock survey must be taken in early June, as in Phase I, in order to obtain a timely estimate of the lamb and calf crop. For reasons explained in Section 4 of this report, June is too early for reliable identification of individual agricultural crops. Moreover, different specifications, including larger scales, stereoscopy, and color photography for spot checking, are desirable for the agricultural survey. Two missions are therefore required to fulfill the dual purpose of this research program.

3.4 Positive Imagery

The second interim report tentatively recommended that photographic positives, either conventional positive transparencies or "reverse-processed" film, should be provided for interpretation in Phases II and III. Further review of the experimental livestock counts made in Phase I has strengthened this conclusion. For example, the sheep in pens at Archer Experimental Substation, Wyoming, were counted on both negatives and positive transparencies; the counts made on the positives proved considerably more accurate. Similar results were obtained by repeating on positives the original counts made on flight line 2 in Colorado.

Phase II will include experimentation with reverse processing. If the range of distinguishable gray tones in reverse-processed film can be made to equal that of normal positive transparencies, then reverse processing will be recommended for Phase III.

3.5 Correlation with Ground Sampling

The correlations between photointerpretation and ground sampling obtained in Phase I have been satisfactory for a basic judgment of feasibility, which was the major objective. However, improved control of photointerpretation, by denser and more precise ground sampling, is necessary for a detailed assessment of reliability and particularly for establishment of a valid confidence level, the major objective of Phase II.

Briefly, the imperfections of the Phase I ground-photo correlations were:

(1) The ground data consisted of total head counts for each type of animal, and some head counts for each breed and age class, to be checked against the corresponding photo counts. For a valid statistical confidence level, correlation of total head counts is insufficient. We must also know whether the photointerpreter's identification of EACH ANIMAL is correct, and if incorrect, why. For this intensity of correlation, not only must every animal in the herd be identified on the ground, but also every animal identified on the ground must be identifiable as an individual on the aerial photographs. From this it follows that the herd must be small enough to be plotted in detail or photographed on the ground in one or two exposures, AT THE MOMENT OF AERIAL PHOTOGRAPHY, so that there will be a permanent record of the identity of each animal. Then any wrong count or wrong identification by the photointerpreter can be explained and corrected.

In Phase I these conditions were fortuitously approached in a few areas, for example, the sheep pens at Archer Experimental Substation, but control of the lamb count here is lacking because the times of counting were different and the exact location of the lambs counted on the ground is not known.

(2) Some of the ground data sheets gave no head counts, but only a general identification of the herd or flock, for example, "mixed Holstein and Hereford" or "sheep and cows." Others gave only estimates of numbers, for example, "about 50 cows" or "90 sheep." In range country, of course, the field man can only make estimates of large flocks or herds, especially those he sees from a distance. This information was useful for checking the type and breed identifications, but not the reliability of counts, made on the aerial photographs. Where the photointerpreter detected more animals than the field man, and where the photo count is reproducible, we conclude that the photo count is better than the ground count.

(3) The area photographed was too large to allow ground counting at or even near the moment of photography. (The field men may not have been told the time of photography or instructed to take their counts at the same time.) Many of the herds noted on the ground data sheets were found on the photographs in different locations, making it doubtful whether the same animals were being counted. Some of the field men noted the time of making each count; this helped to explain discrepancies in location, but not to correct discrepancies in counting.

(4) The sketch-map forms used for recording the ground data were inadequate and, in varying degree, conducive to error. The field men working in Utah used large scales for their map forms, one grid square equal either to one quarter section or to one quarter of one quarter. When their sample areas were plotted on the photographs, only minor inaccuracies of sketching shapes of fields were found. In Colorado and Wyoming, the field men used a small recording scale, one grid square equal to one section, and sketched in very few landmarks such as creeks or railroads. At this small scale, with section numbers the only clue to location, even a minor inaccuracy of drawing creates appreciable error in plotting the area on the photograph, and leads to serious doubt whether the ground count and the photo count are really comparable. In fact, in the course of reviewing the photointerpretation, it transpired that many ground sample areas had been drawn on the sketch-map forms as much as half a mile away from their true locations. In the places where the field men had noted that livestock were present, none were found on the photographs, but similar herds or flocks were found some distance away.

Some of these were across apparent property lines or even across section lines, where it was unlikely that the animals had moved between the times of ground counting and photography. For example, about half the sample areas on pass 13 (flight line 2 in Colorado) and at least two of those on pass 7 (flight line G in Wyoming) were found to be misplaced on the sketch maps.[4] Table III gives sample comparisons between ground counts and photo counts on pass 13. The double uncertainty introduced by the difference in time of counting and difference in location makes these counts statistically valueless.

(5) The field men thought that the panoramic swath width (the width of photographic coverage across the flight line) was greater than it really was, and located many of their sample areas too far from the flight line to appear on the photographs. Owing to an unfortunate misunderstanding, the reasons for which we have been unable to trace in the project records, the Department of Agriculture received the impression that the operational photography of Phase I would be taken from 20,000 feet above the ground, instead of 5,000 to 14,000 feet, and that it would have a scale of 1:20,000 and a swath of 7 miles. In fact, HyAc photography at 1:12,000 and a scan angle of 45° has a swath width of about 5 miles. In Phase I this distance was reduced to about 4 miles of usable coverage because the high shock mounts installed in the aircraft to damp camera vibration caused some vignetting (blocking out of the image) at the ends of the panoramic strip.[5]

The erroneous impression of panoramic swath width persisted, even though Vidya drew a swath of 4 miles on the flight map sheets before forwarding them to the Department of Agriculture field personnel. For example, 14 of the ground sample areas on flight line G in Wyoming are off the image area of the 1:12,000 coverage; one sample area is 2 miles off the photograph. The large-scale passes of Phase I, which cover ground areas only about half as wide as the main 1:12,000 coverage, are almost devoid of usable ground samples. On these passes the only means of reviewing the photointerpreter's counts was to recount the same herds on the same photographs.

---

[4]The field man working on flight line G providentially sketched in a railroad and a creek near the misplaced areas, so that the mistake - in numbering sections - was discovered. Many similar lapses may have gone undiscovered.

[5]The shock mounts can be lowered for Phase II to eliminate the vignette effect and make the 45° camera scan fully usable.

The general reproducibility of photo counts on the large-scale photography has been used to make the basic judgment of feasibility and the recommendation of photo scale for the livestock photography of Phase II (see Section 7 of this report). However, reproducibility is not in itself a satisfactory index of statistical validity.

4. CROP IDENTIFICATION CRITERIA

During Phase I of the program, distinct differences in the appearance of cultivated croplands have been observed in the operational photography. Background study of methods of identifying crop types[6] and crop classes[7] has included a review of previous publications on the subject, of which there are very few. This is unfortunate, in view of the potential economic value of such research.

Available training texts and technical papers were reviewed. The Manual of Photo Interpretation (American Society of Photogrammetry, 1960) is particularly valuable as a text. Chapter 11 of this book presents many valid criteria of crop identity.

The most valuable technical paper found in the literature is "Determining the Prevalence of Certain Cereal Crop Diseases by Means of Aerial Photography," by Robert N. Colwell (Hilgardia, vol. 26, no. 5, November 1956). This paper, which stemmed from work sponsored by the National Research Council's Committee on Plant and Crop Ecology, Division of Biology and Agriculture, has as its objectives:

(1) To determine the photographic scale, film, filter, angle, time of day, season of year, and other specifications necessary for detecting and identifying certain important diseases to be found on oats, wheat, barley, and rye.

(2) To determine the recognition features by which these crops and their diseases might be identified on aerial photographs taken to specifications.

The conclusions are that the mass effects of many types of plant pathogens can be detected in aerial photography, affecting specific types of crops. This implies that at least under certain circumstances crop identifications may be made by identification of the incidence of disease in the specific type of crop,

---

[6] By "crop types" is meant individual crop plants such as wheat, sugar beets, and grapes.

[7] By "crop classes" is meant general categories of crops such as grains, row crops, and vine crops.

but not necessarily by study of healthy crops. It is also pointed out in the paper that comparative analysis of the same fields photographed with different film and filter combinations ("multiband" analysis) aids in identification.

Both the cited technical paper and the significant chapters in the Manual of Photo Interpretation specify that large-scale aerial photography is required for identification of specific types of vegetation, particularly when identification depends upon recognition or using "convergence of evidence" techniques for analysis of the identifying characteristics of individual plants.

The research preceding this and any other publications on crop-type identification is limited by the object and spectral resolution capabilities of cameras older than the HyAc (and other) modern systems.

In further background research, it was found that several years ago an agricultural key was prepared by Northwestern University. Efforts to obtain a copy for review and evaluation were unsuccessful. However, persons who were familiar with the contents of the key indicated that it is limited to a few pictures of fields in Indiana and Illinois, without detailed analysis of "signature" characteristics which permit identification of fields other than those which are actually illustrated.

In this research-investigation, the following identification criteria have been assessed to determine their potential value for crop-type identification:

(1) Size - both of whole fields and individual plants - x, y, and z dimensions.

(2) Shape - both of whole fields and of individual plants.

(3) Shadows - as used to show profile appearance in vertical photography, for calculation of height, and as an indicator of relative heights.

(4) Tone - as an indicator of the amount and spectral quality of light which different types of crops reflect, and of soil moisture.

(5) Texture - as an indicator of stand density, size of individual, closely packed plants, differences in height of individual plants in a closely packed stand.

(6) Pattern - for analysis of characteristic farming practices which might aid in crop-type identification.

(7) Spatial orientation - as an indicator of crop identity by land-use economy - relation of one field to another, and the intensity of cultivation in given areas.

(8) Spacing - of rows, and the distance between individual plants, in certain instances.

(9) Location - of individual fields to optimize plant growth advantages for specific crop types.

(10) Relationship to surrounding features - such as specific types of farm equipment which are required for cultivation of specific types of crops, and specific types of buildings such as corn cribs.

(11) General environment - such as dry or wet land which is required for cultivation of specific types of crops.

Rarely, if ever, can a firm identification be made from any single factor. If several of the listed factors are distinctive of a given type of crop, and imagery is located which conforms to all of them, there is greater probability as to the identity of the crop; for example, if a given combination of tone, texture, pattern, location, and environmental factors identifies wheat, and an image of the field is found which corresponds to all of them, the field is probably a wheat field.

Since crop conditions in the month of June were cited as being of greatest value to the Department of Agriculture, emphasis was placed on determining characteristic signature conditions during that month. However, June is not the best month for positive identification of crop types. Efforts have therefore been made to determine when greatest accuracy in identification can be achieved by aerial survey techniques.

4.1 Time of Year

Time of year is an important consideration in obtaining aerial photography for specialized purposes, particularly agriculture, botany, and forestry. Plants look different during the different stages of their growth cycle. Perhaps the most generally recognized visible seasonal change is flowering; if aerial photography is taken while plants are flowering in the spring, there is greater likelihood that they will be detected and identified. Sown crops, on the other hand, are invisible or barely visible from the air early in the growing season.

The times when seed pods appear, or later, when fall colors appear, are best for obtaining aerial photography for some purposes. April is usually the best month for photographing old crop marks, areas of differing soil fertility, springs and seeps, geologic faults and fracture traces, or "frost pockets" in the soil. In April in the north temperate zone, most species of annual native vegetation have developed only where soil moisture is greatest.

In the High Plains in June, stands of spring wheat and other small grains are perhaps less than one half their mature height, and few characteristic features have developed by which the crops can be identified from a distance. In fact, even a trained agronomist may have difficulty identifying grain crops when they are only a few inches high. After the grains begin to head out, differences become more apparent. Oats, for example, when pictured in oblique aerial photographs, usually appear lighter than other grains (Colwell, 1956).

Identification of row crops in aerial photography is improved at times when:

(1) Transplanting is done.

(2) Individual plants, if of distinctive shapes, can still be seen, that is, before their stems or leaves merge together.

(3) Blossoms appear.

(4) Seed pods or other distinctive fruits appear.

(5) Fall colors appear.

The available spectral reflectance data do not suffice to choose the most suitable period or periods of seasonal growth and the optimum film-filter combination for each period. When data of this kind are collected, time of year will become less critical for agricultural surveys. Present information indicates that the Phase II photography for crop identification should be taken later than was done in Phase I, perhaps in middle to late July if the survey is made in a region similar to the High Plains.

The theoretically optimum season for crop identification will, of course, have to be considered in relation to the time required for the Department of Agriculture to compile usable crop predictions. This subject should be discussed in the planning of Phase II.

4.2 Size

The sizes of whole fields appear to offer little valid information for identification of crop type. Field sizes are influenced more by market demand, acreage allotments, local farming practices, and by terrain than by the type of crop which is being grown.

While field sizes offer little for identification of crop types, they may be valid indicators of the kind and, obviously, volume of production. Large fields are almost certain to be used for commercial production. Small fields are more apt to indicate production for domestic use only, or for agricultural experimentation.

Sizes of individual plants, both plant height and plant diameter, are potentially valuable clues for identification of certain crop types, particularly if individual plants can be seen.

Height differences, as seen in stereo, or as indicated by shadow length, are valid identification clues for identifying between some types of crops.

More research is needed to develop dependable size criteria for individual plants. Size criteria may prove valuable for identification of both row crop plants and cereal grains. However, size criteria are strongly influenced by seasonal moisture conditions, amount of fertilizers used, time (state of maturity), and other factors, and a given set of size criteria will probably only prove reliable in a single geographic area.

A large scale, preferably overlapping to permit stereo study, is required if accurate height measurements are to be made.

Individual plant size as it influences development of "texture" and "pattern" is discussed in the following paragraphs. Spatial orientation and the spacing of rows in certain types of row crops are also discussed later.

4.3 Shape

The shape of whole fields is largely governed by terrain and local farming practices rather than by crop type.

Shapes, both plan and three-dimensional, of individual plants and of isolated rows may aid in identification.

Determination of shape criteria which differentiate crop types as "bush," "low, wide-leaved," "long-stemmed, narrow-leaved," and "bulbous above-ground vegetables" appears to offer promise. Shape criteria are less apt to be geographically restrictive than criteria based on size.

More research is needed to develop dependable criteria in this category.

The mass effect of similar shapes is a strong contributing factor in development of texture and pattern. Texture and pattern are discussed in the following paragraphs.

Distinct registry of shapes of small objects in aerial photography demands that the wavelength of the light which is reflected back to the camera be sufficiently long so that it is not scattered excessively between the object and the camera in the air. The amount of scatter with altitude depends upon haze particles in the atmosphere and, to a certain extent, upon the gaseous components of the air itself. The effects of scatter can be at least partially controlled by selection of an optimum film and filter combination, by selection of the most suitable flying weather (better results are usually obtained under a high, thin overcast, with clear air between the camera and the ground), and by flying at the lowest altitude at which the camera system functions efficiently.

Camera systems are discussed in Appendix A, film and filter combinations in Appendix B.

4.4 Shadow

Shadows offer valid criteria for some crop types if profile views are shown. Since most crops consist of densely packed stands, shadows usually blend together so that identification of a single shadow is not possible.

Shadows along the margins of fields are a valid indicator of the relative height of different types of crops. Determination of dependable shadow criteria, in this respect, is dependent upon size criteria.

Shadows have a strong bearing on tone and texture identification criteria, as will be discussed later.

4.5 Tone

Differences in the total amount and the spectral quality of the light which is reflected from ground objects or areas create different tones of gray in black-and-white photography. Differences in tone stem from differences in the reflectance characteristics of an individual object or densely packed stand of similar objects from their background.

Atmospheric differences, which vary the total amount of light from the sun, obviously have a strong effect on tone values in aerial photographs. Differences in soil color and soil moisture also have a strong bearing on the differences in tone which can be seen in an aerial photograph. Cloud shadows may, of course, totally obscure tone differences in a given scene.

Within limits, tone differences between objects and their surroundings may be controlled and predetermined by the optimum selection of film and filter combinations.

Predetermination of tone values for crop type identification necessitates that the spectral quality and total quantity of the light which is reflected from the crop be known. Ground and aerial spectral reconnaissance is necessary for more exacting measurement and prediction of these values. Ground and aerial spectral reconnaissance is discussed in Appendix E.

Tonal values for identification of crop types may be measured by use of a gray scale. In analysis of projected imagery, or directly on negatives and positives, gray tones may be measured with a densitometer or microdensitometer. Figure 5 illustrates a microdensitometer in use for measurement of tonal values on transparent imagery. Significant tonal characteristics for identification signature criteria may not be uniform shades of gray - they may be varied, or mottled. Localized variations in light-reflecting characteristics may stem from growth density of different crop types; from differences in reflectance between stems, leaves, and heads; from crop disease or insect damage; from state of maturity; or from planting pattern.

Figure 6 illustrates significant multiband tonal differences between oats and wheat which have been attacked by black-stem rust (*Puccinia graminis*). The differences in tone between oats and wheat in different portions of the spectrum permit not only detection of disease damage, but also determination of crop type, because the two grain types reflect differently when diseased.

In background study, it is reported that very little difference was noted in spectral reflectance between healthy wheat, barley, and oats early in the year. These measurements were not made on site, but from cut samples in a laboratory.

In Phase I it was found that there were visible tonal differences between different fields; however, more extensive ground truth information is necessary to ascertain _why_ these differences exist. Both ground and aerial spectral measurements are needed. Figure 7 (exp. 180-181, pass 7, Archer Exp. Sta., Wyo.) illustrates some of these differences.

At this very small scale (1:12,000), it was difficult to distinguish a difference between plots which the Department of Agriculture field man reported as corn and those which he reported as fallow. Some fields which were reported as winter wheat were very dark-toned, others light-toned. Differences this great are improbable, and the ground data may be in error. The dark-toned areas marked as "winter wheat" may in fact be spring wheat.

Pattern differences (distinguishable furrows in corn fields but not in other fields) may provide reliable identification criteria.

4.6 Texture

Texture in aerial photographic images refers to the usually repetitive, mottled tonal variations visible in forests, brush, tall grasses, and other relatively homogeneous surface cover. At a given scale, dense stands of cover materials which are so close together that individual shapes of features blend together appear as a uniformly roughened surface. When viewed in stereo, depending upon the relative differences in height of the surface and the parallax base of the overlapping photography, the roughened appearance becomes more apparent. In the case of different kinds of vegetation, plants which are individually small appear as a fine-textured surface. If the individual plants (leaves and stocks) are larger, the textured appearance will be coarser. Examples are the fine texture evident in the surface of a small grain field (wheat, oats, barley, rye, etc.) and the coarser texture of a corn field. Figure 8 illustrates both tone and texture differences in different types of crops.

Differences in texture between crop types can also be seen when aerial photographic imagery is studied without the added advantage of stereo.

Four factors may work together to create the roughened, mottled appearance which is referred to as "texture." These four factors are:

(1) Minor differences in height.

(2) Shadow patterns which fuse together (stemming from minor differences in height).

(3) Variations in stand density, which may permit the lighter (or darker) toned earth to be visible through the vegetation.

(4) Differences in spectral reflectance between different parts of the individual plants. For instance, the upper and under surfaces of some types of leaves reflect different amounts of light.

Differences in tone combined with texture may yield greater reliability in identification of crop types. This is particularly true in multiband analyses, where some measure of the total spectral quality and quantity of light reflected from individual fields can be keyed with a given texture.

Figure 9 is a tone and texture comparison scale which might be very helpful in identification of crop types.

4.7 Pattern

Patterns as significant agricultural criteria are most evident in orchards, vineyards, and row crops.

Figures 10 and 11 show typical row and grain crops as well as part of an orchard.

In the early part of the growing season, characteristic planting patterns of many types of row crops are much more distinguishable than they are later in the year. As the growing season progresses, stalks, leaves, and vines tend to merge together so that characteristic patterns are obscured. This is very apparent in the case of cotton, beans, sugar beets, and potatoes. In the early part of the year, a potato field is characterized by individual plants about 1 foot in all dimensions, planted about 40 inches apart in rows which are about 40 inches apart.

A significant pattern for cereal grains sometimes can be seen when fields are plowed and harrowed in one direction, and planted or "drilled" at right angles to the furrows. The result is a checkerboard pattern, which can sometimes be seen until the standing grain is quite high.

Significant patterns can also be observed in diked fields in which rice is grown. The dikes form a pattern which, for all practical purposes, is like a topographic contour map. For reasons of economy (see Section 4.8), dike heights are kept to the minimum which is consistent with full utilization of the topography. Figure 12 shows rice fields in California, flooded, as pictured in the infrared portion of the photographic spectrum. Although illustrative examples were not available, the fact that a given crop is rice would be strongly implied by the presence of dikes which followed the topography very closely.

4.8 Spatial Orientation

The term "spatial orientation" as used here is defined as "space economy" or the degree of efficiency used in land management to ensure that the maximum dollar value is obtained from the available land. Row spacing - planting to obtain maximum yield potential for a given ground area - is an important aspect in spatial orientation; a better example is close spacing of beds of separate types of vegetables, which keeps the supply low enough so that demand and market prices remain high.

Figure 13 shows closely spaced truck-garden plots near Oakland, California, as an example of near-maximum land use economy.

Table vegetables must be taken to market and into the hands of the consumer in the shortest possible time to prevent spoilage by bruising, drying out, or decay. This demands that they be grown close to market.

Tone, texture, location pattern, and spacing provide the most reliable criteria for these types of vegetable (row) crops, to support spatial orientation criteria.

4.9 Spacing

Cereal grains are normally planted with a machine called a "drill" so that rows are very close together. Some types of crops (alfalfa, clover, various grasses) are grown as continuous cover and are frequently broadcast-sown so that no rows are formed.

Recommended spacing (distance between furrows) for most types of row crops is 40 to 42 inches. The seeds or individual transplanted sprouts may be planted in one or two closely spaced parallel rows on the ridges between furrows.

4.10 Location

Several factors influence the locations which are selected for cultivation of some crops. Included are accessibility, soil type, porosity and permeability, availability of water, slope of land for drainage, direction of slope for optimum daily and seasonal sunshine, proximity to market, and economic value of crop in relation to land value.

4.10.1 Accessibility

Obviously, all crops which are grown in one location and are moved elsewhere, for local consumption or for market, require access roads or trails leading to them. Perishable row crops, table vegetables, and similar high-value crops which require hand labor will be closer to major access routes and will have better roads and trails leading to them than will crops whose enroute marketing time is less critical. Cereal grains, which are harvested with combines and similar large farm implements, may be economically grown in less accessible locations, except that access routes must be wide enough to permit passage of the type of farm equipment required.

Further research is required to determine whether (a) routes of access for specific types of farm equipment can be identified, based on trackage, and (b) whether the specific types of farm equipment in use are sufficiently restrictive to permit crop-type identification by the use of certain types of farm machinery which leave distinctive trackage.

4.10.2 Soil Type, porosity, and permeability

Just as indicator types of vegetation are clues to soil types, soil types may be reliable crop-type identifiers. The additional image identifiers include tone, texture from run-off, absence of drainage because of better percolation (more permeable soil), and the existence of characteristic native indicator vegetation. More research is needed to accurately classify agricultural soils by image analysis, and to define the suitability of different types of soils for cultivation of specific crops. It may only be possible to class soils in broad categories; even this would be desirable.

4.10.3 Availability of water

Normal rainfall and the need for irrigation or flooding is a valuable signature identification criterion of certain crop types.

The fact that a ground area is wet or dry, subject to seasonal flooding, irrigated, or was deliberately flooded at the time aerial photography was taken can usually be determined in aerial photography. Characteristic "brush-stroke" patterns indicate occasional or seasonal flooding. These patterns are formed by current deposition of soils of different particle sizes, selective growth of native and cultivated vegetation, and similar factors.

Differences in tone are indicators of relative porosity or residual soil moisture. Tone differences which are induced by residual soil moisture are frequently most evident in infrared aerial photography - bare soil, when damp or wet, reflects less IR and registers in darker tones.

Evidence of irrigation in aerial photography includes: (a) presence of irrigation ditches, (b) trenches in fields, (c) presence of pipes and spray equipment on the surface, (d) dark circles in fields where rotary spray equipment is in use, and (e) in otherwise arid or semi-arid regions, lush green vegetation.

Irrigation sometimes has the undesirable effect of leaching salts and some minerals from soils. This may either increase (by re-deposition) or decrease the amounts of these minerals in the soil. In some regions, where the amount of salts has been increased, white (high reflectance) salt encrustations can be seen in parallel bands along irrigation canals, ditches, and trenches.

A general indication of the amount of rainfall in a region is given by the types of native vegetation, percent of ground cover and related factors. More reliable data are available from the U. S. Weather Bureau and from the Division of Water Resources, U. S. Geological Survey.

More background research is required for classification of crops, perhaps in the form of a "regional" agricultural key, so that the number of crop types for which interpreters would look in a given region can be narrowed.

4.10.4 Slope of land for drainage

As a general rule, level land is more productive than hilly land, because of deeper soil horizons (less run-off and surface erosion). Rolling and hilly land is frequently devoted to continuous cover crops and pasturage because of the adverse effects of erosion. Some badly eroded rolling land has been reclaimed by contour plowing and other sound soil conservation practices. Soil conservation efforts being practiced in an area are usually very evident in aerial photography.

More background research is needed to determine if specific practices form reliable signature identification criteria for specific crop types.

4.10.5 Direction of slope for optimum daily and seasonal sunshine

Some crops produce higher yields on sunny slopes than on shaded slopes. Native vegetation in certain regions exhibits distinctive preferences for warm (sunny) or cold (shaded) slopes. Soil on sunny slopes thaws earlier in regions which have pronounced warm and cold seasons, and is usually dryer. Shaded slopes are usually cooler, and the soil more moist.

The location of specific crop types based on angle and direction of slope is largely a matter of regional and local farming practice. More research is needed in this area. Such data might best be presented in a "regional" key.

4.10.6 Proximity to market

Types of crops which perish rapidly are produced closest to market, as a general rule. Based on perishability, certain types of crops can be excluded from consideration near larger towns.

More research is needed to compile a listing of crops on the basis of perishability.

4.10.7 Economic values

Only the more valuable crops can economically be raised on land of high value. Land values in this case are influenced by several factors. Included are proximity to urban areas, markets, water, and the suitability of the land for even higher value crops. Analysis of economic values by aerial photographic interpretation requires extensive regional background research.

While this factor is important for conduct of operational surveys, little effort was expended on it in this research investigation.

4.11 Relationship to Surrounding Features

In the case of identification of specific crop types, the important surrounding features include many of the locational factors which were enumerated in Section 4.10. More research is required, as was stated, for identification and illustration of specific types of farm machinery which might serve as reliable indicators.

4.12 Environment

Many of the local environmental factors were cited in Section 4.10. However, regional environmental factors also play an important part in determining which types of crops can be economically grown in open fields.

It is suggested that environmental factors be considered in preparation of a key, particularily if a regional approach is taken in compilation.

In this research investigation, environmental factors for crop-type identification were given only passing consideration.

5. LIVESTOCK IDENTIFICATION CRITERIA

Figures 14 through 23 contain many examples of the criteria which have been used to identify livestock in the Phase I photography. To some degree the photographs also show the type of illustrative material which Vidya recommends for a photointerpreter's key to livestock. As was stated in the second interim report, such a key should consist mainly of detailed close-up photographs - terrestrial, oblique, and vertical - with related examples from survey photography. If a sample key is to be compiled in Phase II, it will therefore be necessary to obtain a good deal of special photography in addition to the experimental aerial coverage. The oblique and vertical close-ups may be simulated aerial photographs, taken from the tops of buildings, towers, trees, and other suitable vantage points; or they may have to be taken from helicopters.

The series of photographs presented here is incomplete in that it omits the low-altitude oblique color stereograms and the large-scale vertical stereograms, both of which we consider essential for a key. It does, however, serve to relate everyday experience (ground observation) to the unfamiliar impressions presented by vertical photography, and to suggest how keys and other simple training materials can enable the inexperienced interpreter to make accurate identifications.

The following paragraphs discuss the principal identification criteria for common breeds of cattle. All these criteria must be considered in identifying any given image; first the interpreter identifies it as a cow, then as a black cow, then as an Angus cow. In practice these mental processes often take place nearly simultaneously and the identification is easy. In more difficult cases, each criterion must be considered separately and possible identifications eliminated until only one remains.

It is these difficult identifications that a key is designed to facilitate; if all identifications were easy, then only a brief training session for beginning interpreters would be necessary. There may, for example, be some regions of the Western United States where only a few cattle breeds are raised, or where use classes can be correctly distinguished from environmental features. Formal livestock keys to such regions are not necessary. In regions where animal husbandry is greatly diversified, formal keys are probably essential to the success of a livestock survey. However, in each regional key, only those breeds that are actually raised in the region should be keyed out, so that the interpreter need not waste his time eliminating possibilities which do not in fact exist.

A study of the accompanying photographs will reveal that no one identification criterion is always definitive. The shape, shadow, and apparent size of animals may vary according to their stance - grazing, feeding at troughs, lying down, or standing with heads up - and their position with regard to the incident light. A combination of criteria usually yields an accurate identification. If several animals in a herd can be clearly identified but others are doubtful, then it may be a fair presumption that the doubtful individuals belong to the same breed or use class.

5.1 Shape

In the vertical or near-vertical perspective of aerial panoramic photography, cattle have a distinctive shape like this:  with characteristic wide hindquarters and narrow shoulders. Heifers are similar in shape to mature cows, but thinner, with narrower hindquarters. Bulls have wider shoulders and generally blockier builds. Steers are widest at the belly rather than the hip. In general, dairy cattle have more graceful shapes in vertical view; beef cattle tend to be more massive.

The typical cow shape may vary according to the stance of the animal and the angle at which the light falls on it. Shape is usually clearest in light-colored breeds such as Guernseys and Jerseys. In Holsteins and other spotted breeds the shape may be confused by color markings on the back. In Black Angus it may be confused by the black shadow; in fact, Black Angus tend to look blobby and shapeless on photographs because it is impossible to tell where the body ends and the shadow begins.

5.2 Size

Image size is useful chiefly as a relative criterion for age class distinction. Bulls are larger than cows; heifers are slightly smaller than cows; calves are much smaller than cows. Calves might conceivably be mistaken for sheep, but calves usually stand close to their mothers and would probably not be found in a large group resembling a flock of sheep. Moreover, site criteria (see below) for sheep are quite different.

The size differences between otherwise similar breeds of cattle, for example, between Guernsey and Jersey, are not great enough for reliable distinction. Fortunately this particular distinction need not be made.

5.3 Color and Tone

Several of the common cattle breeds can be identified at least tentatively from their color patterns.

(1) Holstein: black and white, varying from all black to almost all white.

(2) Guernsey and Jersey: light brown, appearing in photographs as very light gray to white tone.

(3) Ayrshire: red and white spotted. Many resemble Holsteins in contrasty aerial photographs, in which red color appears as very dark gray tone.

(4) Hereford: red-brown with white face and crest. White markings usually appear clearly even in small-scale photographs. Red-brown body appears as dark gray tone.

(5) Angus: all black.

(6) Shorthorn: red, red and white, or roan color. Red and white individuals may resemble Holstein, but can be distinguished by site and other clues to use, as well as more athletic body build.

5.4 Shadow

Most of the Phase I "operational" photography was taken during the morning hours with a light angle approximating 45°. Animals which happen to be standing broadside to the light cast distinctive profile shadows, which greatly resemble the familiar ground view and are valuable aids to identification. If the animal is standing at another angle, the shadow may be somewhat shapeless, but it does serve to separate the animal from the background and facilitates detection of individuals which otherwise might be overlooked. Shadows of the black breeds tend to be confusing rather than enlightening, but since only one common breed (Black Angus) is all black, this is not a serious drawback.

5.5 Site

Site is the most important single criterion of use class. The photointerpreter must consider both the general type of environment and the detailed features of each type. For example, cattle seen on the open range are almost certainly beef cattle. If they are in a range area, but confined in pens or corrals, they are probably beef, but confirming information (breed if identifiable) should be sought. If they are in pasture or feed lots in an agricultural area, they may be beef or dairy or both; nearby environmental features such as cooling sheds (dairying) and loading chutes (beef) should be considered; breeds should be identified if possible, particularly if the herd is mixed. Combining environmental clues with the shape, size, and color of the stock should serve to establish use class.

6. EFFORTS TO IMPROVE INTERPRETABILITY

6.1 Multiband Analysis

Multiband analysis was restricted to the visible spectrum, the infrared bands having been found less useful by preliminary scanning. Photographs which pictured livestock and cultivated fields were selected from the Milpitas multiband photography obtained by Vidya under Project VELA. Positive transparencies and some paper prints (Fig. 4) were prepared.

Analysis of cattle images such as those in Figure 4 indicated that tonal contrasts between livestock and pasture background are better if both the shorter (400 to 500 mμ) and the longer (650 to 700 mμ) wavelengths of the visible spectrum are eliminated. Livestock appear to be easiest to detect in the spectral region from approximately 500 to 650 mμ.

In order to collect illustrations for the second interim and final reports, 35-mm oblique stereomultiband photography was taken. The filter combination was the Wratten 25A and Wratten 16 (+0.50 neutral density to obtain the same filter factor). The Wratten 25A transmits light from 590 to 700 mμ; the Wratten 16 transmits light from 520 to 700 mμ. Eastman Kodak Plus X and Panatomic X films were used. The photographs were taken from altitudes of 500 to 1,500 feet with a Nikon S-2 camera having a focal length of 35 mm and a prism attachment to increase the stereolens separation to 80 mm. Both films were processed in Diafine. One roll of Panatomic X was reverse-processed to yield a first-generation positive transparency.

6.2 Color Viewing

It is well reported in the literature that the cone vision of the human eye, which is more valuable than rod vision for discrimination of small details, is enhanced by yellow-green light peeking at about 556 mμ. This fact was discovered and described by Purkinje in the nineteenth century.

In Phase I efforts were made to accentuate cone vision by fitting two filters over the projection lens of the large screen viewer: the Wratten 9, which transmits light of wavelengths 470 to 700 mμ, and the Wratten 58, which transmits light of wavelengths 470 to 610 mμ. The same scenes were viewed in succession with the green filter, the yellow filter, and without filter. The results obtained by visual comparison were inconclusive, and more study is required to evaluate color viewing techniques. Itek recommends a testing program in Phase II for evaluation of color viewing, test subjects to be Department of Agriculture employees representative of those who would make operation surveys.

6.3 Stereoscopy in HyAc Photography

The HyAc photography for Phase I was taken with an overlap just sufficient to ensure complete coverage. Some efforts were made to study overlapped areas in stereo, first on the contact paper prints which had been made for orientation and annotation, and then on positive transparencies. Positive transparencies were made of exposures 181 to 184 in pass 7, which cover the Archer Experimental Substation, Wyoming School of Agriculture, and picture several types of row and grain crops at a scale of about 1:12,000. The overlapping areas of these exposures were studied in stereo over a light table and with a Bausch & Lomb stereomicroscope. Stereoscopy appeared to improve the interpretability of crops, although no definitive characteristics of individual crops were noted at this small photo scale. A distinct pattern of furrows was detected in many fields. This pattern was much finer in fields which USDA field personnel reported to be planted to Sudan grass and small grains than in fields planted to corn.

Stereoscopy is undoubtedly valuable in agricultural surveys. Stereoscopy for crop identification in Phase II will be obtained with frame cameras.

6.4 Aerial Color Photography

Images of crops were examined in aerial color photography of agricultural areas in Santa Clara County, California, taken by Itek in 1962. Color differences between different row crops were quite evident. The identity of the crops could not be confirmed on the ground. However, row spacing was different in fields where color differences were observed. From this it is inferred that the crops in these fields were different. Spray irrigation equipment was in use in some of the fields, and the color photography clearly showed damp and dry areas. Orchards in bloom were easy to distinguish from others not in bloom. If the times of blooming of the various fruit trees were known, and if the color of blossoms were captured in color photography, the trees could be identified.

Color photography offers many advantages, not only for crop identification, but also for analysis of farming practices. For usable survey photography, maximum resolution in the color film is necesary. Eastman Aerial Ektachrome MS may be the best choice.

7. RECOMMENDATIONS AND CONCLUSIONS

7.1 Crop Survey

Aerial photographic crop surveys are feasible, but more research is necessary to determine the smallest photo scales at which plants of different types, or the fields in which they are grown, can be accurately identified. It is possible to identify certain crops (rice, for example) at photo scales as small as 1:50,000. Vegetables in small plots or closely spaced beds, on the other hand, do not show reliable identification criteria except at very large photo scales. In the present state of the art, identification and classification of crops in narrow categories is feasible at scales as small as 1:12,000.

Stereoscopic photography having ground resolution of 0.1 foot at a scale of about 1:3,000 may be required, for spot coverage at least, to identify some types of vegetables.

As has been stated in connection with livestock, the development of photointerpretation keys and the experience gained in the initial operational surveys may eventually bring smaller photo scales within the range of usability for crop identification.

Further evaluation is required to confirm the photographic specifications for Phase II. Most crop photography should be taken later in the growing season than was done in Phase I; if possible, after the crop begins to mature.

Photointerpretation keys to crop types will, of course, have to be assembled on a regional basis, because of geographic and climatic differences which affect agriculture. For example, a key might be applicable to the High Plains or to the Upper Mississippi Valley. Where agriculture is highly specialized, separate keys should be constructed for small areas rather than large geographic regions. In California, for example, commercial production of artichokes is concentrated in the Watsonville area, celery in the Salton Sea area; it would be unnecessary to key out these crops for parts of California, or other regions of the United States, where they are not grown.

Vidya recommends a Phase II program following the plan outlined by Professor Colwell at the First Symposium on Remote Sensing of Environment, University of Michigan Institute of Science and Technology, February 1962. This plan is described in Vidya Proposal No. 2015 for Phase II. It includes collection of spectral reflectance data in the field; test multiband photography and field check; compilation of keys; operational multiband photography; photo analysis, field check, and final improvement of photographic system.

7.2 Livestock Survey

The work done in Phase I on livestock identification has developed the following requirements for the statistical proof to be developed in Phase II: (1) minimum photo scale of 1:7,000 to 1:8,000; (2) improvement of tonal range in the photography, including multiband research; (3) positive imagery; (4) improvement of correlation between ground sampling and photointerpretation. To fulfill requirement (4) Vidya recommends the following changes in procedure.

(4a) The Vidya proposal for Phase II recommends two types of HyAc panoramic photography: <u>experimental</u> photography to establish a statistical confidence level, and <u>survey</u> photography to simulate operational conditions.

The <u>experimental</u> photography should be restricted to an area small enough to permit the field men to identify individual animals and record the identification, either on ground photographs or on detailed plot sheets, at the moment of aerial photography. The animals must be closely penned or, if in pasture, staked. The herds selected for ground counting should, if possible, be mixed in breed and age, so that the greatest information can be obtained from the fewest counts. These conditions can most easily be obtained at the agricultural campus or experiment station of a land-grant university, the Davis campus of the University of California, for example.

The <u>survey</u> photography will cover a larger area, capturing representative conditions in agricultural and range country. It will not be possible to record the identity and position of every animal imaged in the survey coverage, but this should be done in predetermined sample areas, just as in the experimental area. For the rest of the survey coverage, head counts may be made as in Phase I.

(4b) For the survey photography, the flight lines, swath coverage, and ground sampling areas should be laid out by agreement between the Department of Agriculture field supervisor and the Vidya aerial photographer, and should be plotted, not only on flight maps but also on aerial photographs for the field men, in the presence of both representatives. (In Phase I many decisions about the "operational" flights had to be made by last minute consultations and phone conversations, creating opportunities for misunderstandings to creep in.)

The annotated aerial aerial photographs may be ordinary 9" by 9" government coverage, of the smallest available scale for ease of orientation, and will be used in the field for recording the position of ground photographs and plot sheets. If no such coverage is available, enlargements of the USGS topographic quadrangels should be used as field maps instead. The use of ordinary aerial photographs or topographic quadrangles for mission planning and ground sampling will obviate mistakes in recording ground data and gaps in photographic coverage, and thus make the ground sample truly comparable with the photointerpretation.

(4c) In the unsampled parts of the Phase II survey area, the Department of Agriculture field supervisor cannot know ahead of time the precise location of livestock. However, he can delineate representative or suspect areas within which the field men are to make head counts, first making sure the areas chosen are within the coverage of the survey photography. The field men can then mark on the base photographs the exact spots where they count herds. The Vidya photointerpreter can use these annotated photographs to plot the gound sample areas and to search the photography for exactly what the field men saw on the ground.

Planning and performing field work to this degree of intensity will not be burdensome if the Phase II experimental photography is restricted to a small well-controlled area, and if an adequate sample of the survey photography is controlled in the same way. In fact, if an agricultural campus such as Davis is photographed in Phase II, it should be feasible to station enough men on the ground to count the entire livestock population of the area within a few minutes of the time of photography. The resulting correlation data will be clean enough to establish a valid confidence level for the operational survey of Phase III.

If the above recommendations are followed in Phase II, Vidya is confident that a photographic livestock survey can be carried out in Phase III to a degree of accuracy acceptable to the Department of Agriculture and, furthermore, that range country can be surveyed more accurately by photointerpretation than by field work.

At the end of Phase I we can only estimate the accuracy likely to be obtained in such a survey:

(1) Type identification and head count for each type (cattle, sheep, horses): within about 3 percent at photo scale of 1:7,000 to 1:8,000 in geographic regions similar to those photographed in Phase I. Some animals will be invisible under trees even if the photography is taken early in the morning. However, it should not be difficult to arrive at a satisfactory correction factor for this type of error by averaging the errors made under controlled conditions in Phase II. Photo counts of herds on the open range and large herds on dairy farms will be better than ground counts, which are made under distracting conditions of movement and perspective. The accuracy of a photographic survey will fall off severely in regions such as Washington and Oregon where ranchers run cattle in the trees. However, it is unlikely that accurate ground surveys could be made in such regions at all, except by techniques similar to those used in cruising timber.

(2) Calf and lamb count: within about 5 percent. Distinction between heifers and cows: variable, according to indications of relative size in the photograph.

(3) Sex distinction of cattle: variable, probably within 25 percent, mostly by interpretation of site and other associative clues. Perhaps should not be attempted operationally.

(4) Use classes of cattle: variable, according to ranching and dairying practices in region. Where herds are not mixed, accuracy should be within 5 percent. Where herds are mixed, accuracy should be within 5 percent if breeds have distinctive color markings, for example, Holstein and Hereford. If breeds lack such distinctive markings, identification of use classes in mixed herds may fail. If the distribution and frequency of mixed herds in the region is known, it may be possible to establish a usable correction factor.

MISSION LOG

MISSION NO. 11/63

N/C & CREW Cessna 180 (N7768A) Brunn and Chadderdon
DATE 9,10,11,12 June '63 **PROJECT OR TEST NO.** 8290
CAMERA Hy Ac **FILM** SO-226
EXPOSURE SETTING f/5 1/450 sec **FOCAL LENGTH** 12" **FILTER(S)** Wratten 21
WEATHER CONDITIONS Clear, scattered clouds 6/9/63; high clouds 6/10/63; haze 6/11/63

PASS NO.	EXPOSURE NOS.	LOCATION	TIME	ALT. M.S.L.	CAMERA ATTITUDE	HEADING	FLIGHT LINE	REMARKS
1	001-006	S.L. City	0815	16.4K	Vert.	E-W	1	(((Flight lines repeated at 10.4K MSL on passes
2	007-041	"	0830	"	"	N-S	2	(4, 5, and 6, respectively. (
3	042-055	"	0845	"	"	S-N	3	(
4	056-068	"	0900	10.4K	"	E-W	1	S.L. flights 6/9/63
5	069-135	"	0905	"	"	N-S	2	
6	136-165	"	0915	"	"	S-N	3	
7	166-235	Cheyenne	0915	18.2K	"	W-E	G	Random P-2 shots
8	236-286	"	0930	12.2K	"	W-E	G	Cheyenne flights 6/10/63
9	287-320	Lara.	0805	20.K	"	S-N	D	Laramie flights 6/11/63
10	321-382	Cheyen.	0825	"	"	NW	E	Light haze and high cirrus clouds
11	383-433	"	0845	"	"	NW	F	First 10 exposures of pass 11 are for exposure control.

MISSION LOG

MISSION NO. 11/63

N/C & CREW Cessna 180 (N7768A)
Brunn and Chadderdon
DATE 9,10,11,12 June '63 **PROJECT OR TEST NO.** 8290
CAMERA Hy Ac **FILM** SO-226
EXPOSURE SETTING f/5 1/450 sec **FOCAL LENGTH** 12" **FILTER(S)** Wratten 21
WEATHER CONDITIONS High Cirrus

PASS NO.	EXPOSURE NOS.	LOCATION	TIME	ALT. M.S.L.	CAMERA ATTITUDE	HEADING	FLIGHT LINE	REMARKS
12	434-479	Greeley	1225	16.5K	Vert	N-S	1	
13	480-591	Greeley (south)	1305	"	"	E-W	2	
14	592-605	"	1330	10.5K	"	W-E	2	Pass starts in vicinity of Bowles Seep Canal (Map 4)
15	606-613	"	1335	"	"	W-E	2	Pass starts just E of pass 14
16	614-620	"	1337	"	"	W-E	2	" " " " " 15
17	621-632	"	1339	"	"	W-E	2	" " " " " 16
18	633-638	"	1340	"	"	W-E	2	" " " " " 17
19	639-643	Greeley	1335	"	"	S-N	1	Starts S end of flight line.
20	644-647	"	1356	"	"	S-N	1	Starts just N of pass 19
21	648-650	"	1357	"	"	S-N	1	" " " " " 20
22	651-653	"	1358	"	"	S-N	1	" " " " " 21
23	654-661	"	1359	"	"	S-N	1	" " " " " 22
24	662-689	Lara.	0905	13.2K	"	NE-SW	B	
25	690-719	"	0915	13.2K	"	E-W	C	
26	720-773	"	0940	17.5K	"	NW-SE	B	
27	774-831	"	1005	"	"	E-W	C	

TABLE I.- SAMPLE CORRECLATIONS OF LIVESTOCK COUNTS, FLIGHT 2 (MIDVALE, UTAH). CONTACT PHOTO SCALE 1:12,000.

Dept. Agric. Livestock Record		Vidya Pass 2			
Sheet No.	Area No.	Exposure No.	Area No.	Field Count	Photo Count
3	4	018	2	4 Hereford cows 2 Hereford calves	6 Guernsey cows
3	5	018	3	45 sheep	43 sheep
4	3	019	-	7 Holstein heifers	(found 6 in PI review)
4	7,8	019	2	61 sheep 25 lambs	80 sheep
5	2,3	020	1	44 Jersey cows 4 horses	32 Holstein cows 14 Guernsey cows
6	1	024	1	27 Holstein heifers	27 sheep
7	4	025	-	1 black steer 1 white steer	(found in PI review, but would have counted as cows)
8	1	032	8	75 sheep	74 sheep
9	6	028	9	40 Guernsey cows 12 Holstein cows	50 Holstein cows 1 Holstein bull (in PI review found 11 Holstein, 40 Guernseys)

TABLE II.- SAMPLE CORRELATIONS OF LIVESTOCK COUNTS, FLIGHT G (CHEYENNE-EGBERT, WYOMING). CONTACT PHOTO SCALE - 1:12,000 TO 1:13,000.

Dept. Agric. Livestock Record: Sheet No.	Dept. Agric. Livestock Record: Area No.	Vidya Pass 7: Exp. No.	Type Location	Field Count	Photo Count	Remarks
1	2	180	Pasture	25-30 horses	27 horses	
1A	60	180-1	Pasture	28 wethers	28 sheep	
1A	11.25	182	Pasture	3 ewes 4 lambs	18 sheep (bracketed with next two rows)	Archer Exp. Sub. Area numbers refer to acreage designations on sketch map. Good comparability with ground data, but low film density; many lambs were missed.
1A	11.25	182	Pasture	5 ewes 6 lambs		
1A	11.25	182	Pasture	3 ewes 4 lambs		
1A	11.25	182	Pasture	8 ewes 9 lambs	15 sheep	
1A	11.25	183	Pasture	5 ewes 6 lambs	9 sheep	
1A	11.25	183	Pasture	8 ewes 9 lambs	16 sheep	
1A	15	181	Pasture	10 ewes 11 lambs	9 sheep	
1A	15	181	Pasture	5 ewes 6 lambs	5 adults 4 lambs	
1A	15	181	Pasture	10 ewes 11 lambs	10 adults 11 lambs	
1A	15	182	Pasture	4 ewes 5 lambs	5 adults 4 lambs	

TABLE II.- CONTINUED.

Dept. Agric. Livestock Record: Sheet No.	Dept. Agric. Livestock Record: Area No.	Vidya Pass 7: Exp. No.	Type Location	Field Count		Photo Count		Remarks
1A	15	182	Pasture	7 ewes 8 lambs		13 sheep		
1A	15	182	Pasture	4 ewes 5 lambs		6 sheep		
1A	26A	181	Field strip	20 ewes 37 lambs		57 sheep		Archer Exp. Sub. concluded.
3	2	194	Pasture near Buildings	13 adult cattle 11 calves 1 horse		18 cows 7 calves 1 bull		
5B	1	23405	Pasture	13 horses		13 horses		Found in different area.
6	4	206-8	Pasture	23 cows		25 cows		Hereford?
6	7	206	Pens	4 bulls				Did not detect; low film density.
7	1	201	Pasture	12 cows 12 calves 1 bull	Total 95 head	8 cows 1 calf	Total 104 head	Cattle described on sheet no. 7 are dispersed; many found in different areas on photographs; comparability of counts doubtful.
7	2	202	Pasture	10 cows 5 calves 7 bulls		10 cows 7 calves 4 bulls		
7	3	204	Pasture	10 cows 16 calves 1 bull		15 cows 14 calves 1 bull?		
7	4	205	Pasture	6 cows		7 cows & heifers 2 calves 1 bull		
7	5	205	Pasture	5 cows 10 calves		17 cows		
			Corral	-		8 cows 9 calves		

TABLE II.- CONCLUDED.

Dept. Agric. Livestock Record		Vidya Pass 7				
Sheet No.	Area No.	Exp. No.	Type Location	Field Count	Photo Count	Remarks
7	9	207	Pasture	12 cows	11 cows	
7	11	206	Pen	1 bull		Did not detect; may be under tree.
7	12	207	Pasture	90 sheep	122 sheep	Found in different area.
8	1	205	Pasture	10 cows	10 cows	Angus?

TABLE III.- SAMPLE CORRELATIONS OF LIVESTOCK COUNTS, FLIGHT 2 (ROGGEN-DACONO, COLORADO). CONTACT PHOTO SCALE - 1:11,500.

Dept. Agric. Livestock Record		Vidya Pass 13				
Sheet No.	Area No.	Exp. No.	Type Location	Field Count	Photo Count	Remarks
6	2	591	Pasture	5 horses 2 colts	5 horses 2 colts	Would have missed one colt without ground check.
7	1	584-5	Feed lot	15 Angus cows 20 Angus calves 25 Angus steers	34 Angus adults & calves	Light film density; probably missed many calves. Could not make sex distinction.
7	3	585	Feed lot	35 dairy cows 30 dairy heifers	75 Hol. & G. or J. cows & heifers	Found 1/4 mile away from area marked on ground sheet.
8	1	575-6	Pasture beside house	3 Hol. heifers 2 G. (heifers?)	3 Hol. heifers 1 G. calf	Other Guernsey may be under trees.
8	2	574	Pasture around house	1 horse 1 G. heifer 18 Angus cows 7 Angus calves 1 Angus bull	1 horse 18 cows 6 calves 1 bull	
8	3	574	Pasture	21 Hol. heifers	22 Hol. heifers	Found 1/4 mile away from area marked on sheet. Without cows in same view to give relative size, might have called them all cows.
8	4	571	Pasture	10 Hol. heifers	9 Hol. heifers	Found nearly 1/2 mile away from area marked on sheet. Lack relative size for age class.

TABLE III.- CONTINUED.

Dept. Agric. Livestock Record		Vidya Pass 13				
Sheet No.	Area No.	Exp. No.	Type Location	Field Count	Photo Count	Remarks
8	5	570	Farmstead	10 J. calves 11 J. heifers 16 J. cows	21 G. or J. cows	Count low: some cows are bunched, some may be under trees.
8	6	571	Corral	17 Hol. cows	17 Hol. cows	Found 1/2 mile away, across road.
8	7	571-2	Pasture	5 Hol. cows 1 shn. calf		Did not find.
8	7	571-2	Corral	87 mixed Hol., Hfd., Br. Sw. steers & heifers	85 mixed beef & dairy cattle	Found 1/2 mile away. Light density, count difficult. Identified Hereford by white faces but did not recognize Brown Swiss; could not distinguish sex or age.
11	1	556	Pasture	40 Hol. & Ayr. cows & heifers	20 brown cows & heifers; 1 G or J. cow	Found about 1/8 mile from area marked on sheet; others in feed lot in adjacent section.
11	2	552-3	Pasture near windmill	30 beef cows 21 calves 1 bull	37 cows	Found 1/2 mile away; did not find windmill. Could not identify breed, use class, or age.
11	3	558	Pasture	10 Hol. heifers 6 G. heifers	27 Hol. 12 G. or J.	Found in feed lot, same farm. Age distinction uncertain.

TABLE III.- CONCLUDED

Dept. Agric. Livestock Record		Vidya Pass 13				
Sheet No.	Area No.	Exp. No.	Type Location	Field Count	Photo Count	Remarks
11	4	555	Pasture	34 Hfd. cows 12 Hfd. calves 14 J. cows 6 J. calves 5 Hol. calves 2 horses	8 Hfd. cows 1 Hfd. bull? 13 J. or G. cows 16 Hol. cows	Possible Hereford bull under tree. Others may be under trees. Could not distinguish age.
12	1	592-30	Feed lot	200 mixed cattle	300 mixed cattle	Found 1/4 mile away, across section line. Identified Hereford, Holstein, Guernsey or Jersey. Estimate includes corrals back from road. If this is the same herd noted on data sheet, then PI count is more accurate than ground count.
13	1	495-6	Pasture	About 50 Charlois	56 cattle	Found 1/4 mile away, across road. Dark-colored, so may be different herd (cf. ground photograph no. 2-4).