USE OF REMOTE SENSING FOR LIVESTOCK INVENTORIES

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1. INTRODUCTION

The Statistical Reporting Service, USDA, has for many years employed conventional enumerative methods of collecting livestock inventory numbers by species. Each June and December interviewers visit nearly 17,000 area sampling units. Traditionally, these sampling units are delineated on aerial photographs which serve as an essential tool in acquiring data in the field. The sampling units are subdivided on aerial photographs into tracts of land under the control of a single rancher or farmer. The livestock inventories are then obtained by on-the-ground enumerators for each of the tracts.

During the past four years, the Statistical Reporting Service has been sponsoring research to explore remote sensing techniques which might facilitate the acquiring of livestock inventories. In 1965, Dr. Robert N. Colwell gave a report to the Agricultural Research Institute on the progress and potential of using current aerial photography for livestock inventories. Since that time research by the personnel of the Forestry Remote Sensing Laboratory, University of California, has led to the development of aerial photographic techniques which employ several films, filters, lenses and scales and which also entail new approaches to image analysis. This multiplicity of image specifications and analyses has led to greater accuracy and the possibility of reliances on remote sensing methods as an independent source of information for use in making livestock inventories.

These techniques were tested in a recent experiment in April of 1967 in the Sacramento Valley of California covering an area of approximately 1,000 square miles. The area was divided into two basic land use types. (1) predominantly cultivated farmland and (2) predominantly rangeland. Sixteen area sampling units were selected at random out of each stratum Conventional Statistical Reporting Service inventory techniques were used to acquire inventory numbers by species as well as to classify each field on each ranch (or farm) tract into one of four "domains of interest". The "domains" corresponded to the extent or degree to which remote sensing was believed to be feasible. As soon as possible after the conventional Statistical Reporting Service inventory data were obtained, aerial photographs, flown to previously derived specifications, were secured for these same area sampling units. Through air-to-ground communications, teams were simultaneously stationed in randomly selected fields in each of the "domains of interest" to enumerate the livestock by species, in accordance with standard procedures previously used in Statistical Reporting Service livestock surveys. Preliminary analyses of the results indicate that comparable inventory numbers are obtained by ground enumeration and photo interpretation except for those "domains" where buildings, man-made shading devices, or trees obscure part of the animals from aerial view.

2. REVIEW OF PREVIOUS RESEARCH

As indicated by the following description, several years of research sponsored by the Statistical Reporting Service of the USDA and conducted by the Forestry Remote Sensing Laboratory at the School of Forestry and Conservation, University of California at Berkeley, has established the feasibility of detecting, identifying and counting livestock from aerial photography flown to the correct specifications and interpreted by properly trained personnel.

In 1964, simulated aerial photography of various livestock surveys was obtained by taking vertical photos from the 150 foot high catwalk of a water tower on the Davis Campus of the University of California. Using this stationary platform a great many film filter combinations were tested at various sun angles using a target array of animals of known breed, age and sex. At the same time, several actual aerial photographs were taken of the target array from several altitudes in order to determine if the simulated aerial photography from the water tower could be used for a valid evaluation of film filter and sun angle studies. Subsequent examination showed a good correspondence between the simulated and actual aerial photos; therefore, those combinations showing no promise from the stationary platform experiment could be eliminated from costly aerial testing.

During the next two years research was conducted on fourteen test sites representative of California rangeland and pastureland in order to further determine optimum film filter combinations and arrive at specifications for scale, season of year and time of day. As areas were flown to the various specifications under consideration, ground crews simultaneously obtained information concerning animal numbers, breed, age and location by means of photographs, sketches and notes. Ground information collected simultaneously with the aerial photography is essential in evaluating the interpretation of the aerial photography since a time difference of only a few minutes may give quite varying counts because of the mobility of the animals.

As a result of the feasibility studies from both fixed platform simulated aerial photography and actual aerial photography from sites representative of rangeland and pastureland, probable optimum photographic specifications in terms of film, filter, scale, season of year and time of day were determined for California conditions.

FILM-FILTER: Panchromatic films proved to be the most acceptable when considering both cost and effectiveness. Although interpretation from color transparency film was shown to give greater accuracy, particularly for identification of animal type and breed, its use is considered too costly for complete sample coverage unless part of the cost can be borne by other potential users of the photography. Tests with infrared film and a Wratten 89B filter show that contrast between sheep and a green grass background is inadequate for consistent identification; however, cattle can be identified under these conditions. Against a brown grass background neither sheep nor cattle can be consistently identified on infrared photography. Of the several panchromatic films tested, none was considered to have marked superiority. High resolution is desirable, but many of the very high resolution films are too slow to be used under marginal lighting conditions likely to be encountered in operational situations. The slower shutter speed required can result in serious motion blur. In practice, many moderate speed films (preferably with extended red sensitivity) are satisfactory. A Wratten 12 filter, commonly used in pan minus-blue aerial photography, increases contrast and haze penetration and darkens shadows to give a more interpretable image. Use of a Wratten 25A filter results in more dense shadows and greater contrast between animal and green grass, but since it cuts out even more light its use may not be feasible under marginal lighting conditions. Dense shadows moreover, may be both a blessing and a burden. Animals in sunlit areas are more easily identified and counted if their shadow is dark; however, the dark shadows cast by building, trees and other features obscure those animals within the shadow and prevent their inventory.

SCALE: Aerial photo interpreters of agricultural resources are usually asked to work at the smallest scale commensurate with the accuracy required because of economic constraints. This scale will be the threshold of success or failure and therefore must be accurately specified. Our tests indicate that a scale as small as 1/8000 is often satisfactory, but that a scale of no smaller than approximately 1/5000 is necessary for the making of livestock inventories with consistently high accuracy. The smallest useful scale is governed by how closely the many factors affecting interpretability approach optimum.

SEASON OF THE YEAR: For the purposes of aerial photo inventory of livestock, California has two seasonal states, summer-fall (brown grass) and winter-spring (green grass). On panchromatic film, green grass appears dark and uniform particularly when using filters as discussed earlier, and provides a sharply contrasting background for the counting of sheep, and an adequate contrast for the identification and counting of cattle. Brown grass registers grey in tone on panchromatic film and provides poor contrast for the identification of both sheep and cattle. In addition, the background vegetation is usually much less uniform during the season when the grass is brown. The optimum time of year, then, is early spring after the winter rains are over, but before drying has proceeded to the point that the vegetation on shallower soils is turning brown and giving a mottled appearance to the vegetative cover. At this optimum time of year irrigated and non-irrigated areas provide the same background and, therefore, provide more homogeneous interpretation conditions for the interpreter. Furthermore, in early summer many of the livestock from the Central Valley are moved to mountain pastures and inventory in the valley reveals few animals.

TIME OF DAY: Livestock tend to seek shade during the heat of the day. Therefore, it is necessary to take the aerial photography during the first few hours after sunrise or during the hours just before sunset. At these times the animals are most likely to be in the open where they can be photographed. However, photography taken during the early morning and late afternoon hours has several inherent disadvantages. The low sun angle provides poor lighting and requires increased exposures. This may preclude the use of high resolution films, as explained earlier. In addition, the shadows of natural and structural features such as trees, steep slopes, and buildings are longer and obscure a larger area in which livestock cannot be seen. Despite the disadvantages of low sun angle, it is obvious that the photography must be taken while the livestock are in the open and visible to the aerial camera. Moreover, long animal shadows are an aid to animal identification because they often present a profile representation of the animal. Shadows are particularly helpful if the animals are small or contrast poorly with their surroundings so as to be just at the threshold of recognition.

STEREOSCOPIC COVERAGE: Tests indicate that the accuracy obtained by specifying sixty percent overlap between photos and utilizing the stereo viewing more than compensate for the approximate 20% increase in scale that could be afforded with non-stereo coverage. Stereoscopic coverage provides two views taken from different points in space and time. In addition to the obvious advantage of viewing both the animals and background in three dimensions, the different perspective provided by each view often allows an identification to be made on one photo that could not have been made on the other. Object movement, a certain means by which to differentiate between livestock and objects such as rocks and hay bales, is apparent due to changes in location or posture of animals between successive photos.

During January 1966, a training session was conducted at the School of Forestry, University of California for the purpose of demonstrating the use of aerial photography for the inventory of agricultural resources. The session provided those in attendence with training in the handling and interpretation of aerial photography for the inventory of livestock.

The results of this training session and the feasibility studies which preceded it were sufficiently encouraging to suggest that an operational type aerial photo inventory of livestock be conducted in a relatively large area of California. The area chosen by personnel of the Statistical Reporting Service for this inventory covered approximately 3,000 square miles and was located in the northern Sacramento Valley.

The area was inventoried by obtaining complete photographic coverage of eight sample strips, each approximately three miles wide and from twenty-five to forty miles in length. Five of the strips were photographed at a scale of 1/6000 and the other three at a scale of 1/8000 in order to further compare the effectiveness of these scales. For several of the strips, oblique aerial photography of medium to large concentrations of livestock was obtained from a low flying aircraft, to test this technique for obtaining a separate estimate of the livestock population for the strip.

The photographic specifications used for this inventory were as previously outlined with the notable exception of time of year. The inventory was conducted in June in order to coincide with the annual inventory conducted by the Statistical Reporting Service and thereby utilize the trained enumeration personnel and conventional sample plots and techniques as a check against the photo interpretation. Range vegetation was dry by June and provided a brown background which contrasted poorly with most of the livestock.

Because of poor air-to-ground communication and the large area to be covered, it was not possible to enumerate all the ground segments at the time of aerial photography. Many differences between photo count and ground count were attributable to the time differential; therefore, photo interpretation accuracy could not be well judged for these areas.

3. DESCRIPTION OF 1967 EXPERIMENTAL SURVEY

The research objectives of this experiment were twofold: (1) The primary and most immediate goal was to determine the feasibility of making livestock inventories from aerial photography flown to optimum specifications under operational survey timing. (2) The secondary objective was to determine the feasibility of identifying crop types and land use patterns from aerial photos of the survey area. This report deals only with the livestock inventories findings.

The survey took place in an area of about 1,000 square miles in the Sacramento Valley of California. The test area was about twenty miles wide, west to east, and fifty miles long, north to south. The area was divided into nearly equal parts with the western half being predominantly rangeland and the eastern half being mostly cultivated land. The range stratum as defined for this survey had considerable natural cover along the western boundary of the test area. Sixteen segments were randomly located in the range stratum. These segments were approximately three square miles in area and utilized natural or man-made boundaries such as fences and roads. In the cultivated stratum, sixteen segments were randomly selected in such a way that eight were one mile by one mile and eight were one mile by one-half mile in dimensions. A flight strip five miles long was associated with each of the 16 cultivated segments. This strip had a width of either one mile or one-half mile depending on the width of the segment. The flight strips were determined by constructing all possible strips of five miles by one mile (or one-half mile) where the segments were one mile wide in the cardinal directions and choosing one of the possible strips at random.

In previous work the ground truth had frequently been found to be unsatisfactory because of the inability of ground crews to cover large areas at the time these areas were being photographed from the air. Furthermore, lack of communication between the plane and ground crews had resulted in differences in timing and to consequent uncertainties in the later evaluation. Also, the selection of target areas had been based on rather inadequate knowledge of current location of animals. This fact had resulted in there being a rather meager basis for the evaluation of aerial photographic interpretation methods. To help reduce these difficulties, two-way radios were considered desirable for the ground crews and an observer in the plane; furthermore, it was considered necessary that the target areas be enumerated prior to flight time to obtain advance information on animal locations. Hence, prior to the aerial surveys, teams visited the 16 range and cultivated segments to obtain crop and livestock information on a field-by-field basis within the operator tracts. Based on this information, the number of ground truth data points needed to cover the area sampling units at flight time was ascertained as well as the extent of visibility for viewing the livestock. Each ground crew was assigned to clusters of sampling units so that no two of their check areas were consecutive aerial targets; therefore, they would have sufficient time to move to their next assignment ahead of the aircraft.

Simultaneously with the aerial photography, ground crews obtained accurate ground counts and took ground photographs of animals. Any discrepancies between conditions found in the fields at the time of flight and those reported during the pre-survey enumeration were to be reconciled by further visits to the ranchers and farmers. The ground crews thus provided for each domain a measure of bias from:

(1) animals not visible in the photographs, and

(2) animals visible in the photographs but not counted by interpreters. The ranchers were informed that some checks would have to be made to determine any changes that occurred in the interim between the enumeration by ground crews and the taking of aerial photography.

Since one of the objectives of the experiment was to evaluate how well livestock could be identified in the relation to different types of land use of ground cover, each field was classified as being in one and only one "domain" during the initial interview as follows:

Domain 1 was defined as any field which contained any man-made shields which might obscure animals from an aerial view. Man-made shields were meant to be such structures as barns, sheds, animal shades, bunks, feed racks and windmills. Trees or tall bushes may or may not have been present.

Domain 2 embodies an abundance of natural tree cover within the field, i.e., over 5 percent of the field was obscured from the air by natural cover.

Domain 3 was defined as fields with trees and tall bushes along the border of the field, but with 5 percent or less tree or tall brush cover within the field.

Domain 4 applied to "open" fields that contained no tall obstructions that would help conceal animals from the aerial view.

When a field had any Domain 1 characteristics this domain was assigned rather than other possible domains, i.e., Domain 1 was given preference over all other domains in the classifications. This was done to insure uniformity and because man-made structures were more easily and uniquely identified in the interview with the rancher.

To reduce the amount of ground sampling necessary to adjust the photo inventory count and to test the feasibility of aerial photo interpretation as an independent inventory technique, subsampling with small format, large scale color photography was added to the system for the research conducted in 1967. The photographic aircraft was equipped with two cameras that were operated simultaneously. Complete stereoscopic coverage of the sample segments at a scale of 1/5000 were obtained on Plus x Aerographic film with a Zeiss RMKA camera having a 6 inch focal length and a 9 x 9 inch film format. Color transparencies at a scale of 1/2140 were simultaneously obtained for a subsample of the segment area on Ansochrome D-200 film with a Hulcher camera having a 14 inch focal length Schnieder lens. The film format was 57 x 57 mm. The color photos comprised the central portion of selected flight strips. Color photography of all cultivated flight strips was taken resulting in a subsample of about 40 percent of the panchromatic area. In the range stratum two of the flight strips covering each segment were to have color photography. The designation of the two range flight lines was done on a random systematic basis from the pilot's flight plans submitted to obtain complete segment coverage. The color coverage in the range amounted to about 14 percent of the segment area. The photographic coverage was obtained from April 28 to May 1 after a 12 day delay due to inclement weather. Photography was limited to morning hours due to cloud buildup in the afternoons. The resultant photography was of good quality and the spring green grass conditions provided an excellent interpretation background.

4. PREPARATION AND INTERPRETATION OF AERIAL PHOTOGRAPHY

The panchromatic photography was printed on semi-matte finish paper in order to facilitate making the many delineations required for statistical control. Fine lines were required to avoid obscuring animals. Upon receipt, the prints were assembled into loose mosaics of each segment and checked for completeness of coverage. The exterior boundaries of each segment were delineated and the effective area of each photograph was determined and outlined. Within the effective area of each photograph, ten cells of approximately equal size were delineated and numbered in serpentine fashion (see Figure II). The two center cells, i.e., number 3 and 8, were made to coincide with the area covered by color photography. Because of scale and format size relationships, the color and panchromatic photographs were exposed with different time interval regimes. Therefore, due to changes in aircraft attitude between exposures, there is no constant spacial relationship of the color photography to the panchromatic photography. As a consequence, the areal coverage of the color photography had to be plotted on the panchromatic prints by simultaneous viewing of both films. At the same time, the overlap lines from the effective area of the panchromatic prints were transferred to the color film. These delineations could not be made by the regular project interpreters because of the possibility of introducing bias into the subsequent interpretation of the panchromatic prints as a result of having seen the large scale color film. The process of transferring delineations was troublesome and time consuming for this inventory, but can be eliminated in the future. By using a different format and scale relationship, the two films can be exposed simultaneously for every photo. The resulting constant spacial relationship should allow the use of templates for the delineation.

The photo interpretation for this inventory was performed by two semi-skilled interpreters. They also performed that part of the photo preparation and delineation which could be done without introducing the possibility of bias into the subsequent interpretation. The interpreters were trained for livestock identification and inventory with materials constructed and assembled during the previous three years of research. Simultaneous aerial and ground photographs for many types of animals in various background situations were used in the training. Over 2,000 aerial photographs from the inventory conducted in 1966 were available for inspection.

Folding lens type stereoscopes with a choice of 2 or 4 power magnification were used for viewing the panchromatic prints. The uncut color film was viewed over variable intensity light tables at up to 8 power magnification. Animal counts were recorded by cell number for the effective area of each photograph; therefore, animal counts from photo interpretation could be compared with ground enumeration for small areas as well as for entire segments.

Each interpreter examined approximately half of the panchromatic prints and half of the color transparencies. In order to eliminate the possibility of interpreter bias due to previous viewing of an area, each man was restricted to interpreting the panchromatic photos only or the color photos only for any segment.

After completion of the interpretation for the first several segments, the results were compared by both interpreters while viewing the black and white and color films in concert. The data sheets from their original interpretation were not revised, but the interpreters were able to re-evaluate their previous judgments in light of the greater information provided by simultaneous viewing of both types of photographs. The discussions between the interpreters and others which resulted from this re-evaluation provided excellent additional training upon which the interpreters could base their remaining interpretations.

5. PRELIMINARY RESULTS AND SOME COMPARISONS

The experimental data are summarized in Tables 1-3 for the Cultivated Stratum and Tables 4-6 for the Rangeland Stratum. Image counts and conventional enumeration data are compared in Tables 1 and 4. Results for the Cultivated Stratum were encouraging with the comparable totals for all species of animals being quite satisfactory, but there were important discrepancies by species for individual sampling units. For segments 5C and 6C important differences were observed, several initial errors by one interpreter were associated with small groups of sheep being incorrectly classified as cattle and a herd of cattle being housed inside buildings. The differences in segments 12C and 14C for sheep are the results of several factors. In segment 12C the differences are associated with the animals being located among trees and in buildings. For segment 14C a combination of factors is probably involved: The enumerated data probably represent only approximately the number of mature animals with the image count being subject to some degree of uncertainty due to the clustering of animals. The observed correlation coefficient between the conventional enumerated data and the image counts were .997 for cattle, .944 for sheep, .105 for other species and .933 for total animals.

The results for the Range Stratum sampling units appear to exhibit all of the sources for differences found in the Cultivated Stratum except with somewhat greater frequency and increased magnitude. The differences in segments reflect both difficulties in classification and in counting clusters of animals on the photography; for example, segments 2R and 4R. In addition, discrepancies in image counts due to natural cover seem to occur more frequently than that due to buildings. However, the enumerated ground data (see segments 9R, 10R, & 11R) are also subject to uncertainties which are not as common in the Cultivated Stratum. Boundaries that permitted livestock to move freely in and out of the segment were problems in several range segments, e.g., 15R and 16R. The observed correlation coefficient between the enumerated data and the image counts were .920 for cattle, .818 for sheep, .394 for other species and .810 for total animals in the range stratum.

The relationship in Table 2 by domains seemed to be fairly consistent and not unexpected for the Cultivated Stratum. The corresponding ratios in Table 5 for the range are subject to a greater degree of instability and hence require a larger experiment than the present study. However, part of the instability in these ratios is probably due to the ground data not being known without error. The ratios for sheep are greater than cattle for both strata. There seems to be a paradox for cattle in that individual cattle may be easier to count on small scale photography because of less clustering and their larger size, but cattle are more frequently housed by man. The interpretability for numbers of animals for the sample strips and frames with both large scale color photography and small scale black and white are about the same. The combined use of both films and scales does result in increasing the accuracy of counts of both cattle and sheep by about 5 percent for the flight strips and somewhat less for individual frames. These results are summarized in Tables 3 and 6. The corresponding comparisons for sample fields checked while the aircraft was over the sampling units yielded results similar to those in Tables 1 and 4. This suggests that the use of enumerated data for sampling units which have been rechecked for livestock numbers during the period of the flight would be valid for establishing relationships by "domains" for estimation purposes using double sampling techniques.

The results for the Cultivated Stratum appear to be satisfactory with the reliability for total animals being good. Most of the important differences between image counts and ground data methods are the result of shielding of animals from the camera lens or of the animals being too tightly grouped to count individual animals accurately at the scale of the photography being used. In the range stratum, the same basic sources for discrepancies are found but these are compounded with several additional difficulties. The greater frequency of background clutter, i.e., objects difficult to differentiate from animals and number of photos which must be interpreted may result in isolated animals or small herds being missed. The ground data is also less accurate. The use of more large scale color photography than was obtained in the 1967 test will be required in the range for counting animals in clusters. The large scale color photography also gives the photo interpreters familiarization and provides a built in "training mechanism" for unfamilar areas.

The experiment also provides some information on costs of alternative techniques and photo time requirements. Some comparitive costs are shown in Table 7. The costs shown do not include pre-survey planning or overhead costs. An additional cost which should not be overlooked is the cost incurred to up-date the ground enumeration data to the time of the aerial photography. During the 1967 experiment 12 days elapsed between the enumeration date and the occurrence of suitable weather for photography.

The interpretation time per photo per sampling unit is primarily a function of the background clutter and number of livestock present. For the Cultivated Stratum this average time varied from a low of approximately two minutes per photo per sampling unit when no livestock were present to a high of 22 minutes per photo when a large number of animals were present in a sampling unit. In the range the time varied from a low of 3 minutes per photo for sampling units with no animals visible to a high of 18 minutes per photo when a large number of animals were present in a sampling unit. The most time consuming sampling units to interpret were those with clutter background, several species and a large number of animals present in the same area.

6. SUMMARY AND CONCLUSIONS

The use of aerial photography for livestock inventories obviously has limitations since livestock are not detectable under man-made or dense natural cover. The combined use of aerial photography and simultaneous conventional area sample enumeration methods must be employed to estimate livestock in all "domains". With both ground data and image counts avialable, corrections for bias in image counts due to specific cover types can be made and employed in double sampling estimation methods. It is also clear from the experimental results that it is necessary to adjust image counts where detection of animals by aerial photos is limited to total animals and when certain classifications of animals within species, such as by age, weight, or sex, are desired. However, certain benefits of aerial imagery do result: (1) The access to remote areas is accomplished rather easily, (2) Large areas of land are covered rather quickly, (3) The possibility of the elimination of certain bias resulting from imperfect communication or lack of respondent knowledge or cooperation, and (4) The opportunity for objectivity in counts of animals. Thus, it seems likely that the use of aerial photography to supplement conventional enumeration methods can lead to an improvement in the quality of livestock inventory statistics.

More efficient techniques and equipment for rapid and accurate interpretation of large quantities of photographs are needed before undertaking operational surveys. It would be desirable to have the interpretation phase of the work designed so each individual interpreter's errors enter into the analysis as a randomized error component. An alternative procedure might be to employ sampling inspection techniques for each interpreter's work.

The use of aerial photography would be advantageous in a data collection system employing photo coverage of a large number of sampling units with ground enumerated data being obtained simultaneously on a subsample of the same units. Such a double sampling procedure would have the advantage of providing independent estimates of the total number of animals in the feasible "domains" and securing the needed adjustments ratios for "domains" which provide man-made or natural cover for animals. The accumulation of experience from surveys with the "domain ratios" which adjust for shielding of animals from the camera lens might also permit making livestock inventories with photography as an independent source if biases resulting from using historical ratios could be allowed in the estimation of inventory numbers.

The basic features of the photographic aircraft for an inventory system would be two cameras that could be operated simultaneously to secure panchromatic stereoscopic coverage at a scale of approximately 1/5000 and color transparencies at 1/2500. The use of black and white photography for full coverage of sampling units and large scale color photography for a random sample of sub-areas as well as for all compact groups of animals appears necessary to provide the desired accuracy, particularly for identification of animal type and breed. An observer in the aircraft with a view of the flight path is necessary to locate the compact groups of animals as well as to assist ground crews in determining the exact location of animals with respect to poorly defined sampling unit boundaries in the range stratum. The sub-sampling of areas using large scale color photography would probably be at a rate of 1/10 or 1/15 of the segment area for livestock inventory needs based on experience acquired to date. In addition, the color film would be quite valuable for crop identification if the time of year coincided with the growing season for the crops for which acreage inventory information is desired.

The first effort to introduce remote sensing into an existing data collection system might be done most judiciously by incorporating it into the quality control or re-enumeration phase of the survey. Remote sensing under these circumstances could improve the quality of the inventory data, help determine costs, "domain ratios" and other survey parameters more precisely than has been possible to date. In terms of the present 17,000 area sampling units which SRS employs for data collection a 1/10 subsample would be expected to provide an adequate sample for quality control and to provide inventory numbers for the U. S. The subsample for the average states would be of the order of magnitude of the 1967 experiment. Obviously, a major tooling up operation would be required to effectively use this small amount of information for making current livestock inventory estimates within the customary 3 to 4 week period permitted from the start of data collection to release of estimates to the public by the Statistical Reporting Service. Nevertheless, a small step must be made before remote sensing can hope to contribute to the improvement in the quality and accuracy of livestock statistics in the U. S.

Before undertaking a survey of the above magnitude, some additional research and testing is necessary to utilize the two techniques of data collection most efficiently. The next research which is proposed is to undertake operational scale surveys in several states adjoining California. In the Mid-West where hogs are an important species of livestock a similar test is necessary. In addition to the experience to be gained in coordinating the work under operational timing, modification of procedures is required in order that handling of large volumes of photos in the interpretation phase can be more efficiently accomplished.

TABLE I: COMPARISON OF IMAGE COUNTS WITH GROUND ENUMERATION OF LIVESTOCK NUMBERS FOR AREA SAMPLING UNITS--CULTIVATED STRATUM

Sampling Unit Number	Livestock Species						All Species	
	Cattle		Sheep		Other			
	I.C.	G.E.	I.C.	G.E.	I.C.	G.E	I.C.	G.E.
1	45	47	0	0	0	0	45	47
2	0	0	0	0	0	1	0	1
3	0	0	0	0	0	0	0	0
4	22	25	184	180	0	3	206	208
5	135	182	0	1	8	1	143	184
6	202	255	0	0	15	0	217	255
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	2	0	0	0	0	4	2	4
11	0	0	0	0	0	0	0	0
12	58	61	314	608	6*	0	378	699
13	0	0	0	0	0	0	0	0
14	0	0	1,373	1,000	0	0	1,373	1,000
15	0	0	0	0	0	0	0	0
16	41	43	0	0	5*	1	46	44
Totals	505	613	1,871	1,789	34	10	2,410	2,442

* Cattle incorrectly identified as horses

TABLE II: RATIOS OF IMAGE COUNTS TO GROUND ENUMERATION FOR LIVESTOCK NUMBERS BY DOMAINS FOR FIELDS CHECKED DURING FLIGHT--CULTIVATED STRATUM

Domain	Livestock Species			All Species
	Cattle	Sheep	Other	
1. Fields with Structures (Houses, barns, livestock shades, and other structures)	.710	2.167	8.000	.874
2. Fields with Natural Cover (Trees, brush, etc. cover more than 5% of area)	.000	---	1.000	.042
3. Fields with Border Cover (Trees or brush along border of field, but less than 5% cover of area)	1.008	1.015	0.000	1.007
4. Open Fields (No trees or structures present)	.995	1.341	.500	1.277
All Domains	.849	1.311	1.835	1.181

TABLE III: IMAGE COUNTS FOR 5 MILE FLIGHT STRIPS WITH BOTH SMALL SCALE BLACK AND WHITE AND LARGE SCALE COLOR PHOTOGRAPHY--CULTIVATED STRATUM

Method of Image Analysis	Livestock Species						All Species	
	Cattle		Sheep		Other			
	No.	Ratio to 3	No.	Ratio to 3	No.	Ratio to 3	No.	Ratio to 3
1. Color only	624	.953	903	.956	68	1.063	1595	.960
2. B & W only	626	.955	888	.943	35	.547	1549	.933
3. Combined use of B & W with Color	655	1.000	942	1.000	64	1.000	1661	1.000

TABLE IV: COMPARISON OF IMAGE COUNTS WITH GROUND ENUMERATION OF LIVESTOCK NUMBERS FOR AREA SAMPLING UNITS--RANGE STRATUM

Sampling Unit Number	Livestock Species						All Species	
	Cattle		Sheep		Other			
	I.C.	G.E.	I.C.	G.E.	I.C.	G.E.	I.C.	G.E.
1	235	309	126	114	0	21	361	444
2	0	245	1860	1185	5	0	1865	1430
3	0	0	1066	928	0	0	1066	928
4	22	165	2594	2367	1	1	2617	2533
5	367	400	395	460	7	0	769	860
6	0	0	778	1054	0	0	778	1054
7	0	0	207	1000	0	0	207	1000
8	236	412	5	500	3	0	244	912
9 1/	17	225	533	1500	0	0	550	1725
10 1/	181	225	749	1500	0	0	930	1725
11 2/	0	0	6387	21,000	1	0	6387	21,000
12	61	127	4365	3863	0	9	4426	3990
13	0	0	1905	1103	3	0	1905	1103
14	100	127	1700	2000	0	0	1800	2127
15	483	658	947	2040	6	0	1430	2698
16	61	60	1682	3353	0	11	1743	3413
Total	1763	2953	25,299	43,967	26	42	27,088	46,962
Total less 9, 10, 11	1565	2503	17,630	19,967	25	42	19,211	22,492

1/ Operator did not know the location of 450 cattle and 3000 sheep which were assigned equally to segments 9 & 10.

2/ Operator with 21,000 sheep was hard of hearing, sheep were apparently in the process of being moved at the time of photography.

TABLE V: RATIOS OF IMAGE COUNTS TO GROUND ENUMERATION FOR LIVESTOCK NUMBERS BY DOMAINS FOR FIELDS CHECKED DURING FLIGHT--RANGE STRATUM 3/

Domain	Livestock Species			All Species
	Cattle	Sheep	Other	
1. Fields with structures (Houses, barns, livestock shades, and other structures)	1.077	2.667	.409	2.449
2. Fields with natural covers (Trees, brush, etc. cover more than 5% of area)	.457	.975	1.500	.847
3. Fields with border cover (Trees or brush along border of field, but less 5% cover of area)	.654	.310	1.300	.345
4. Open Fields (No trees or structure present)	.646	.848	.125	.837
All Domains	.625	.933	.618	.898

3/ Units 9, 10, and 11 omitted from ratios.

TABLE VI: IMAGE COUNTS FOR SAMPLE FRAMES WITH BOTH SMALL SCALE BLACK AND WHITE AND LARGE SCALE COLOR PHOTOGRAPHY--RANGE STRATUM

Method of Image Analysis	Livestock Species				All Species	
	Cattle		Sheep			
	No.	Ratio to 3	No.	Ratio to 3	No.	Ratio to 3
1. Color only	104	.972	606	.992	710	.989
2. B & W only	105	.981	603	.987	708	.986
3. Combined Use of B & W with color	107	1.000	611	1.000	718	1.000

TABLE VII: COSTS OF DATA COLLECTION PER SAMPLING UNIT

Data Collection Phases	Range Stratum Units Averaged 3 square Mi.	CULTIVATED STRATUM 1 square Mi. Units	1/2 square Mi. Units
Cost of Ground Enumeration:			
Single Enumeration	$ 41	$ 40	$ 28
Up-date to flight period	21	20	8
Total 1/	62	60	36
Cost of Photo Analysis:			
Acquiring photographs	157	63	25
Delineation of units	25	7	2
Image counts by species	28	10	3
Total 2/	210	80	30
Average Number of Photos for complete B & W stereo coverage	39.8	8.4	2.8
Average Interpretation time per B & W photo (Minutes)	8.3	7.8	6.1

1/ Salary rate $2.50 per hour and travel 9¢ a mile

2/ Salary rate $3.25 per hour for interpretation and delineation of units. The costs include both panchromatic stereo coverage and color photography.