ROBERT A. RYERSON
HAROLD A. WOOD
McMaster University
Hamilton, Ont., Canada

Air Photo Analysis of Beef and Dairy Farming

The technique is applied in Southern Ontario, using black-and-white photos, to inventory the number of each type of cattle.

ABSTRACT: *Using, as a point of departure, recommended feeding systems for cattle of different types and the ways in which cattle are housed within barns, it has been possible, using air photo interpretation, to determine, with an average level of accuracy greater than 92 percent, whether a cattle-raising farm in Southern Ontario has a dairy or a beef emphasis and how many cattle are kept on the farm. The methodology can be applied quite satisfactorily using ordinary black-and-white panchromatic photographs provided that the photo scale permits the measurement of building dimensions to an accuracy of approximately two feet and provided that they were taken at a time of year which permits an interpreter to identify corn, small grains, hay, improved pasture, and rough pasture.*

INTRODUCTION

THE USE OF AIR PHOTOGRAPHS in the study of agricultural land use has, in the past, tended to be limited to the identification, through photo interpretation, of specific crops and of areas affected by certain crop diseases. As ordinary black-and-white panchromatic photographs are of limited value in such work, especially if the interpreters are inexperienced, recent research, attempting to improve the accuracy of land use interpretation, has stressed the use of special techniques, such as sequential photography, or special types of sensors, including narrow-band, color, and false-color photography. By the use of these methods, it is hoped that various elements in the agricultural environment will reveal their presence directly, and in a manner which therefore lends itself to the application of automatic or semi-automatic procedures.

The purpose of this paper is to demonstrate the merits of the alternative approach to air photo interpretation, one which uses indirect methods to arrive at the desired results and can therefore more readily be applied using only conventional black-and-white photographs. As with any study from which precise results are to be obtained, the inputs must be carefully selected, but it will be demonstrated that this selectivity can be no less successful if applied to data relating to land use methods and controls than if based on knowledge of the kinds of radiation which are being emitted by the ground and recorded on the film. Indeed, the procedures outlined in this paper have been found to give, for beef and dairy farms of Southern Ontario, precise information which could probably never be read directly from photographs of any kind or scale.

More specifically, a method of air-photo interpretation is described which permits a determination of the kind of livestock-raising operation which is practiced on the beef and dairy farms of Southern Ontario and of the number of cattle to be found on each farm.

An important feature of the methodology is that it includes two entirely separate approaches to the solution of the problem, one based on land use and the other on building size and type. As it is possible to compare the results obtained from these two independent procedures, the method contains an internal check on its accuracy. The comparison may also enable the interpreter to determine which

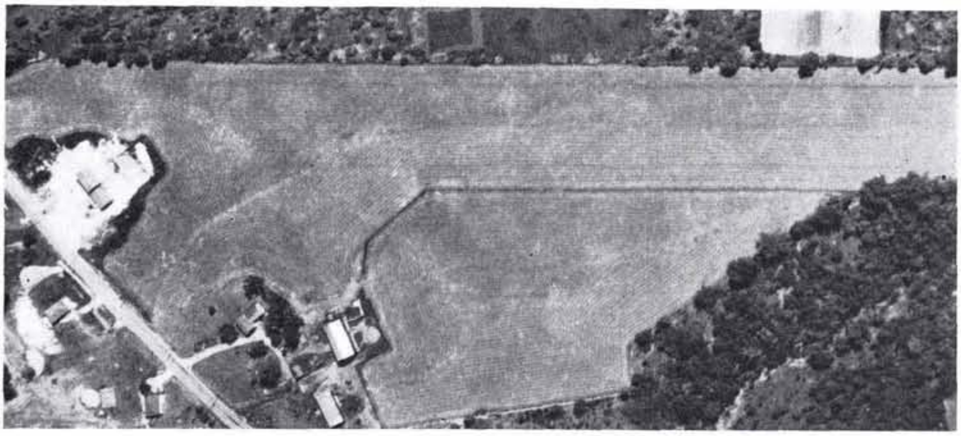


FIG. 1. Air photo patterns for principal crops for feeding cattle in Ontario. 1A—Hay field on June 26 just after the mowing operations has been completed, but before the hay has been removed from the field. Hay is almost invariably harvested in a round-the-field pattern, regardless of the shape of the field.

farms are being operated in a manner which is *normal* for Southern Ontario, and which farms have some *unusual* feature. The meaning attached to the terms *normal* and *unusual* will be made apparent in the discussion which follows.

The methodology makes the following assumptions:

1. That the interpreter is able to measure the dimensions of farm buildings with an accuracy of approximately ±2 feet.
2. That the interpreter is able to identify the following land uses: corn, small grain, hay, improved pasture, rough pasture.
3. That the interpreter can locate the boundaries of the area operated by each farmer.

For the first of these assumptions to be satisfied, it is only necessary, of course, to obtain photographs with sufficient clarity of definition and of large enough scale. In the present instance, the scale of the photos used was 1:12,000, and measurements were made with simple instruments. With more sophisticated equipment, smaller scale photographs would have been usable.

Any photo scale which satisfies the first assumption will also be adequate for the second. Furthermore, ordinary black-and-white photos are quite suitable for the simple crop differentiation that is required, provided that the photo interpreter has had some experience in crop identification and that the photos were exposed during July, August, or September. During these months, corn is easily recognized, whereas small grains, hay, improved pasture and rough pasture may be differentiated one from other by the different working patterns and textures which appear in the photo images (Figure 1).

The recognition of farm boundaries is also

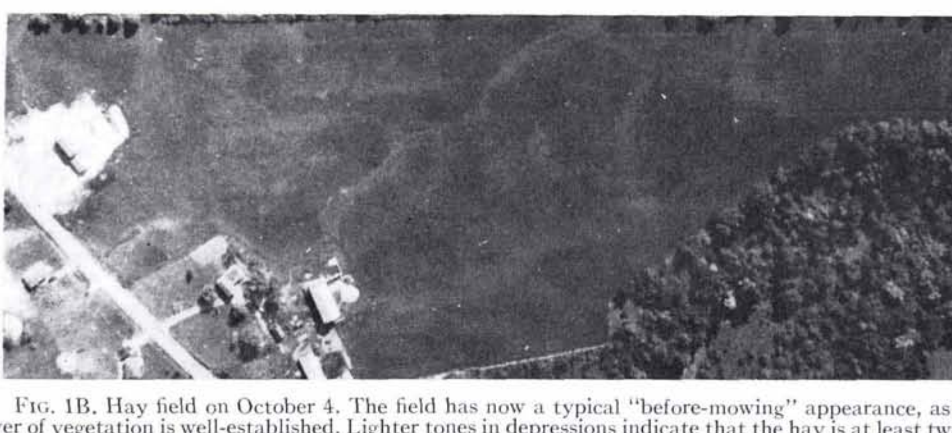


FIG. 1B. Hay field on October 4. The field has now a typical "before-mowing" appearance, as the cover of vegetation is well-established. Lighter tones in depressions indicate that the hay is at least two or three years old; after this length of time, the alfalfa and clover die out in poorly drained parts of the field, leaving behind the lighter-toned grasses of the hay mix.

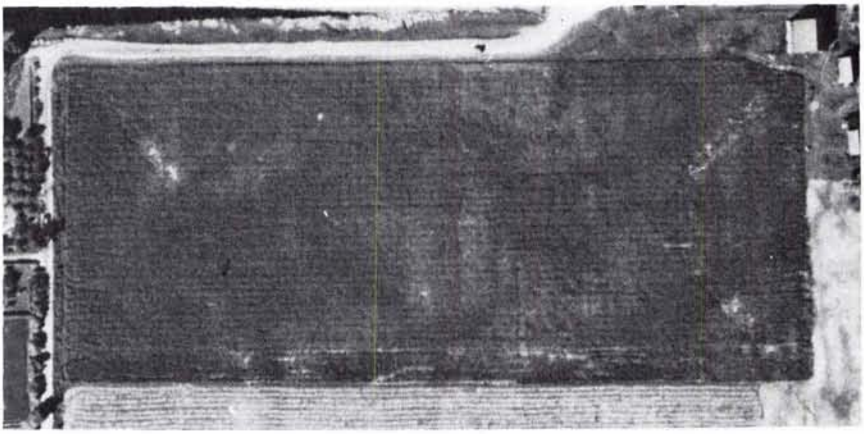


FIG. 1C. Corn field on August 10. The heavy row-planted crop, with its dark tones and carpet-like texture is easily identified, especially under a stereoscope where its height may be appreciated. Diagonal lines in the field corners are traces of the previous year's harvesting patterns, indicating that the field was formerly planted in small grains.

not difficult in the great majority of instances because, in Southern Ontario, most farm units still conform to the original survey pattern, which is clearly visible on air photos of medium scale. Where a farmer is also working an additional piece of land adjacent to the basic surveyed farm unit, that fact will generally be revealed by the tracks of farm vehicles. The only really serious difficulties arise if a farmer owns or rents extra land at some distance from the home farm, to which he travels along a public road. Actually, the use of the methodology outlined in this paper will pinpoint farms which might possibly be using such dispersed holdings, and careful air photo study can resolve at least some of the problems. These instances, however, are relatively rare, involving less than 5 percent of all farms in the areas studied.

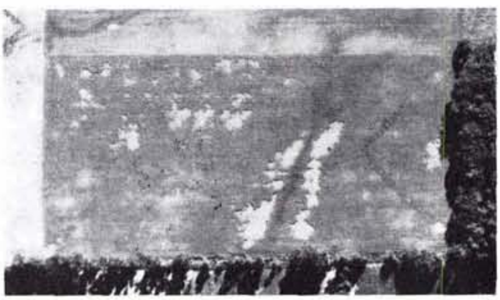


FIG. 1D. Oat field on August 10 just before harvesting. Light patches represent "blow-down," which is particularly common in oats due to the weakness of the plant stalk. Diagonal lines in the field corners are traces of the previous year's harvest operations. Superimposed on them are the end-to-end lines of the more recent seeding pattern.

The data used in the study were drawn principally from four widely separated areas of Southwestern Ontario and referred to below as major sample areas (Figure 2). Each covers about ten square miles, and was selected because of its special agricultural emphases. Thus, the Wentworth area is essentially dairy-oriented. At Wardsville, the emphasis is on cash crops. The Huron and Owen Sound areas are used for general farming, but the former also produces cash crops, including vegetables. All areas were photographed in 1968, and all except the Huron area at the above-mentioned scale of 1:12,000. For the Huron area, use was made

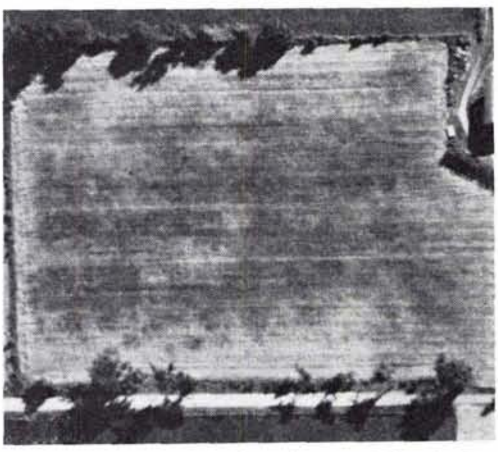


FIG. 1E. Wheat field on August 19 just before harvesting. Slightly mottled tones indicate uneven ripening of grain. Blowdown is not apparent. Seeding was from end-to-end of the field (not necessarily indicative of wheat).

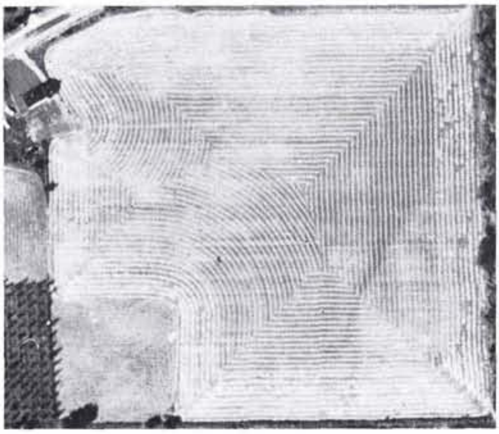


FIG. 1F. Oat field on August 10 just after harvesting with a 6½-foot combine. Smaller combines are of the pull type and normally work around the field. This pattern is also common with fields of irregular shape. Larger combines, with a swath width of 8 feet or more, are generally self-propelled, and tend to work from end-to-end of the field, particularly if it is in the shape of a rectangle.

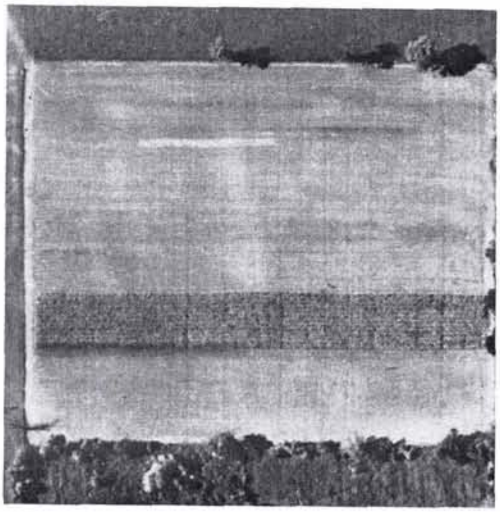


FIG. 1G. Partly harvested corn field on October 4. The texture and pattern of the standing corn are not much different from those to be found earlier in the growing season, but the tone is somewhat lighter. End-to-end harvesting by rows is typical of corn, which is also the only field crop being harvested in Ontario as late as October.

of photographs taken for the Canada Department of Agriculture at the scales of 1:8400 and 1:3600. Field checking was done in 1968 and 1969.

In each of the four major sample areas, all beef and dairy farms were studied in detail, except for those which extended so far outside the area covered by the photographs that a satisfactory inventory of land use could not be made; the total number of farms was 83, or approximately 21 per sample area. Elimination of a farm from consideration because of lack of cooperation of the farmer was necessary in only two or three instances.

In addition to the four major sample areas, sixteen other areas in Southern Ontario were

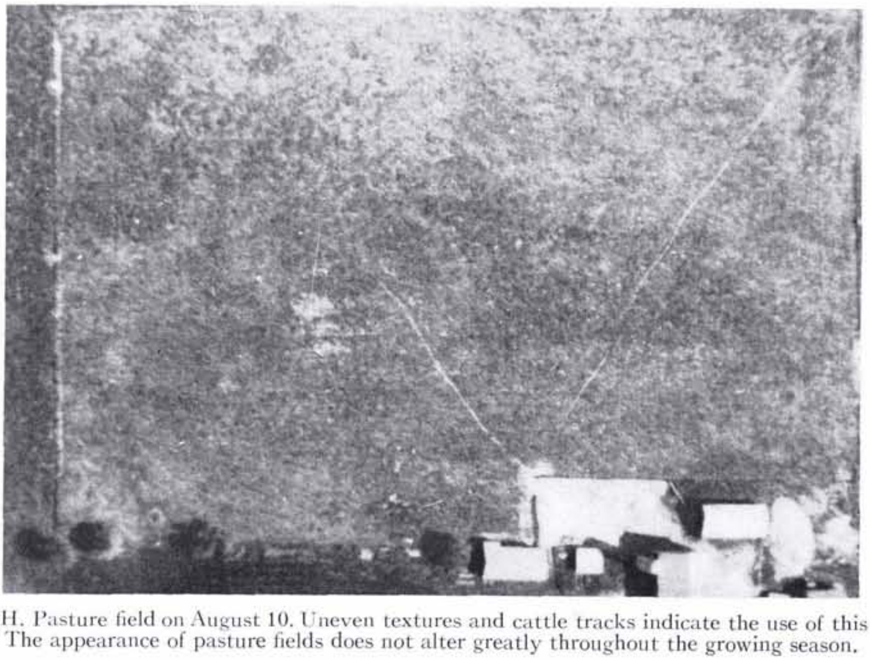


FIG. 1H. Pasture field on August 10. Uneven textures and cattle tracks indicate the use of this field. The appearance of pasture fields does not alter greatly throughout the growing season.

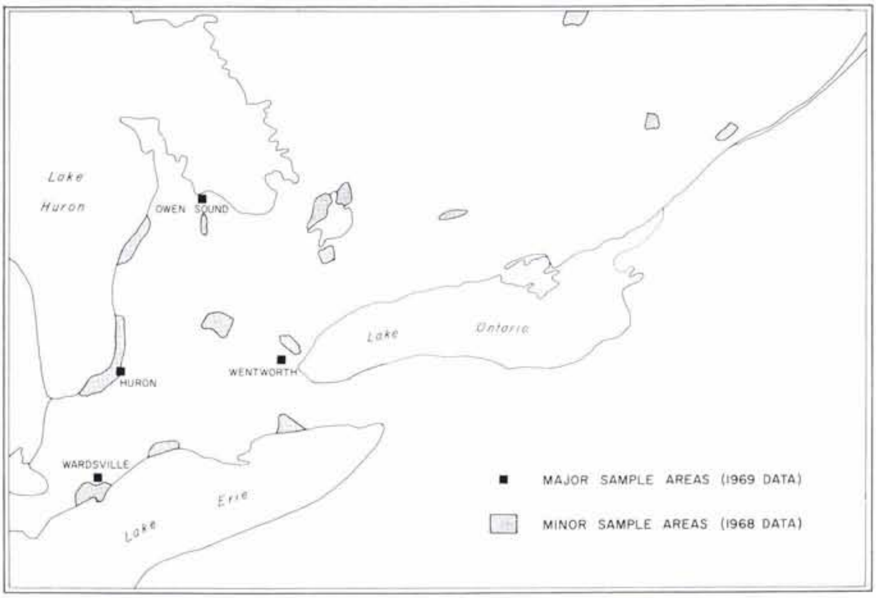


FIG. 2. The four areas in Southwestern Ontario, Canada, from which the data for this study were derived. Each area covered about 10 square miles.

studied in somewhat less detail (Figure 2). Within these areas, referred to as minor sample areas, the number of farms included in the study totals 269.

METHODOLOGY

1. DETERMINATION OF FARM TYPE BY LAND USE ANALYSIS

The key to the application of land use analysis in determining the type and number of cattle to be found on any given farm lies in the feeding recommendations laid down in publications of the Ontario Department of Agriculture.[1] These recommendations are quite specific in two senses. First, they indicate, for a number of *feeding systems*, the feed composition in terms of grains, corn silage, and hay or grass roughage. Secondly, they lay down the type and amount of feed required per day, per head of cattle, according to the type, age and weight of animal.

For both beef and dairy operations, a considerable number of different feed mixes are recommended, each of which is quite clearly designated as being suitable for beef or dairy cattle; no all-purpose feed systems are recommended. Each farmer may choose the feed mix, appropriate to his type of operation, which he finds it most convenient or profitable to adopt. What is significant in terms of the present analysis, furthermore, is that each feed mix or feeding system can be expressed in terms of a set of equivalent crop acreages.

The acreage conversions were based, in the first instance, on the average crop yields obtained in Wellington County,* chosen because of its central location in Southern Ontario, even though it contains none of the major sample areas. Using these yields (Table 1) it is easy to calculate the numbers of acres of hay, corn, and various small grains which a farmer would need to produce the ingredients of any recommended feed-mix in any given quantity. Reference to any specific quantity may then be eliminated if the acreage required for each of the three feed components is expressed as a percentage of the acreage required for all three combined. Then, as the three percentages obviously add up to 100, they can be graphed simultaneously on a triangular diagram, in which each recommended feeding system can be located as a point (Figure 3A).

The result of this operation is a clear-cut,

[1] *Dairy Husbandry in Ontario*, Ontario Department of Agriculture and Food. Publication No. 519, Toronto, Ontario.

Beef Husbandry in Ontario, Ontario Department of Agriculture and Food. Publication No. 509, Toronto, Ontario.

Also various papers from *Soils and Crops Branch*, Ontario Department of Agriculture and Food. 1967 and 1968. Toronto, Ontario.

* To use the figure for just one county constitutes, of course, a simplification, but one which has apparently given rise to few if any, difficulties in the latter stages of the analysis.

TABLE 1. AVERAGE CROP YIELDS IN WELLINGTON COUNTY, 1961–1967

Crop	*Bushels per Acre*[1]	*Weight per Bushel*[2] *(in pounds)*	*Yield per Acre (in pounds)*
Wheat (winter)	38.2	60	2,282
Oats	56.2	34	1,616
Barley	46.6	48	1,911
Mixed grain	56.1	41	2,337
Fodder corn (tons)	12.2		24,400
Hay (tons)	2.2		4,400

[1] *Agricultural Statistics for Ontario.*
[2] *Dairy Husbandry in Ontario.*

though relatively complex, grouping of points within the triangle. A neat division into one dairy area and one beef area does not emerge; rather, two distinct parts of the triangle correspond to dairy feeding systems and three parts to beef feeding systems. Expectedly, no feeding systems are located in the upper part of the triangle. Where over half of a farm's acreage is devoted to small grain, the grain is normally sold for cash or fed to hogs rather than to cattle.

It is now convenient to designate clearly the dairy and beef areas of the feed triangle by the drawing of boundary lines as shown in Figure 3B. The lines were drawn so as to run equidistant between each pair of neighboring dairy and beef points.

The next step, that of locating actual farms on the land-use triangle, following measurement on air photos of the acreages devoted to different crops, involved two refinements. One was the use of yield figures for the county in which the farms are located and for the year in which the photographs were taken. The second was the recognition that all roughage does not come from fields of cultivated hay; an important fraction may be derived from fields classed as pasture. To deal with the difficulty, use was made of a formula[2] which equates the feed produced from one acre of improved pasture with the production from 0.6 acres of cultivated hay. Rough pasture was more arbitrarily converted into a hay equivalent assuming that its feed value would be one-half that of improved pasture. In other words, one acre of rough pasture was taken as equivalent to 0.3 acres of hay.

[2] Johnson, R. W. "*Increasing the Yields of Alfalfas.*" Ontario Soil and Crop Improvement Association. 1967.

By noting the positions occupied on the land-use triangle by the farms studied in the field, it was then possible to test the hypothesis that beef farms use *beef* feeding systems whereas dairy farms use *dairy* feeding systems. Thus, for the 269 farms of the minor sample area, it was discovered that in 88 percent of all instances, dairy farms fell within the dairy areas of the triangle and beef farms within the corresponding beef areas. For the farms of the major sample areas, 63 of the 83 were found to occupy the expected triangle locations.

To obtain some insight into the reasons why some farms turn up in the *wrong* part of the triangle, a separate examination was made of the 20 *anomalies* from the major sample areas. Of the 12 beef farms located in a dairy part of the triangle, it was discovered that 4 were run by part-time farmers; 5 were cow-calf operations, which used a *dairy* feed mix for the cows when they were in calf, and the remaining 3 farms took in feeder beef cattle on a temporary basis; the owner of the animals lives elsewhere, and may remove them to his own property for a part of the year. Of 8 dairy farms located in the *beef* sections of the triangle, 4 were run by part-time farmers, one had a cash crop emphasis, one buys all his grain feed, one was holding land for speculative purposes, and one had 25 beef cattle in addition to its dairy cattle.

The results of this test were taken to indicate that the hypothesis may, in general terms, be accepted. At the same time, support is provided for the assumption, implicit in the entire approach, that most dairy and beef farmers in Southern Ontario produce on their own land the bulk of the feed which is consumed by their cattle.

In addition, it was discovered that the land-use ratios may be used to provide information about the type of operation which is carried out on any given beef farm. Thus, a triangle location allocating over 45 percent of the acreage to corn was found in every case to identify the beef farm as a steer feeding operation, in which young animals are bought and fattened for the market during a period of approximately six months, after which they are sold. A triangle location in which small grain occupies over 38 percent of the acreage invariably indicated a beef/hog or beef/cash-crop operation (Figure C3).

Cow-calf beef production is not identified by location on the land-use triangle alone, but definite relationships with land use patterns exist nonetheless. Of 7 beef farms located within that part of the dairy area D1

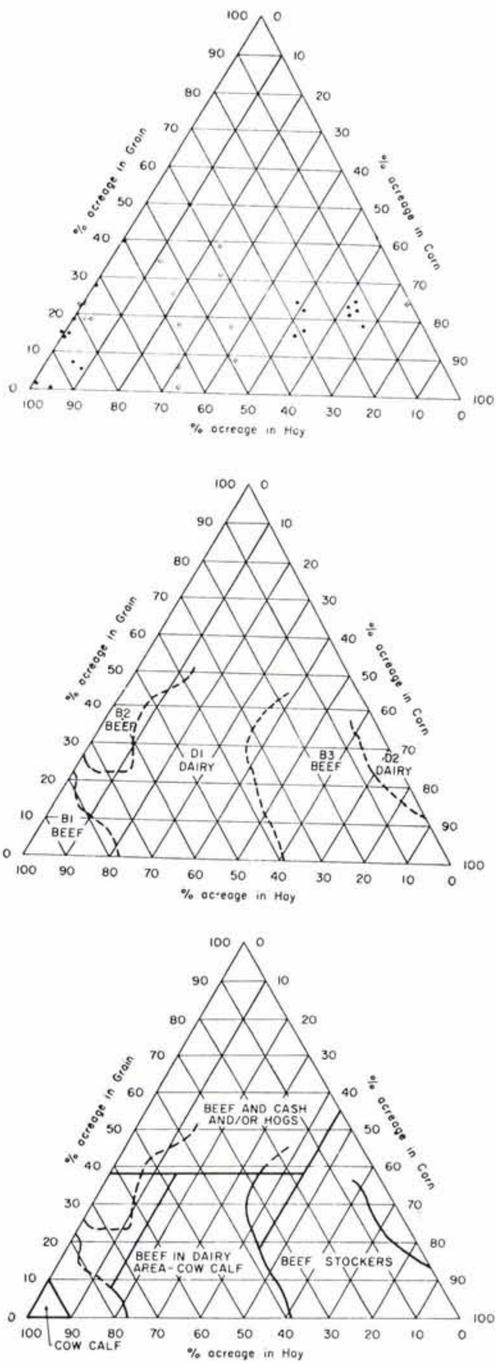


FIG. 3. The land-use triangle. *A* (top)—Land-use ratios for recommended feeding systems. A solid dot represents a beef farm and open dot a dairy farm. *B* (center)—Differentiation of farm type by land-use ratios. *C* (bottom)—Differentiation of beef farms by land-use ratios.

where 15 to 45 percent of the acreage is in corn, 6 are cow-calf operations. In that part of the beef area B1, where over 90 percent of the acreage is in hay, 7 out of 11 farms are also of the cow-calf type (Figure 3C).

2. DETERMINATION OF FARM TYPE BY BUILDING ANALYSIS

Dairy Farms. From an examination of farm buildings of Southern Ontario, as they appear on air photos of the scale 1:12,000, the most useful indication of dairying is the presence of a milkhouse, a small square structure projecting outwards from the main barn. In addition, with free stall[3] barns, a milking parlor will be present, easily identified by its shape and size (Figure 4).

A few dairy farms (about 10 percent of all instances) have no milkhouse or milking parlor. Some of these farms produce industrial milk, and do not need milkhouses. In other cases, the milkhouse is within the barn, where it escapes detection on air photos. In a few instances, the presence of a milk-loading platform beside the road may provide an alternative clue to the emphasis on milk production.

Beef Farms. Absence of a milkhouse and, in many instances, the presence of pole-type barns are indicators of a beef operation. A feed-lot, or large fenced-in earth-floored area adjacent to the barn, indicates that the farmer is feeding beef for weight gain.

A pole barn is typically a long narrow structure running along one or two sides (generally the north and west) of a rectangular yard. The side of the barn which faces the yard is of open construction. Alternatively, a pole barn may be built in the form of a lean-to on the side of an older conventional type barn (Figure 5).

STEPS ONE AND TWO COMPARED

Where the farm type has been identified by the two methods of land use and building analysis, and where the results agree, they may be accepted with complete confidence. In a number of instances, however, the results are found to be conflicting. Under these conditions, the following assumptions were found to be applicable in the present study:

- Where the land use points to a dairy operation, but no milkhouse and/or milking parlor

[3] A free stall barn is divided into stalls, but the cows are not tied in the stalls. Alleyways between stalls are paved.

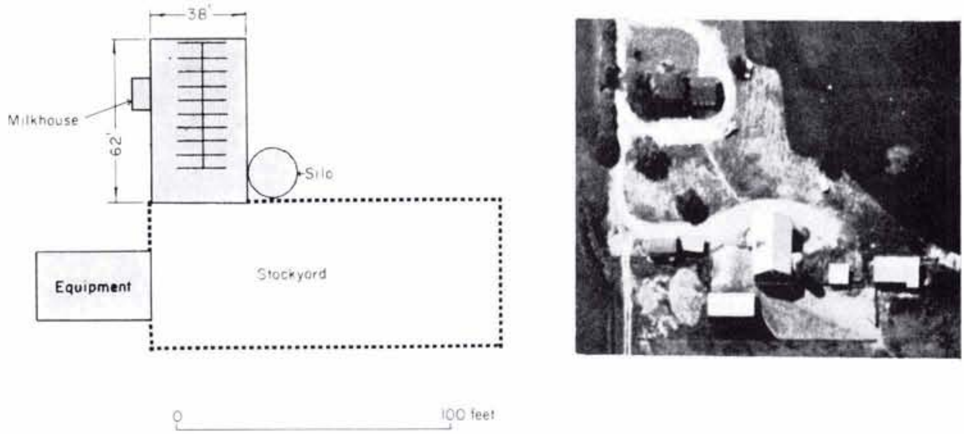


FIG. 4. Housing arrangements for dairy cattle. 4A—Housing in unmodified conventional barn with tie stalls. Barn dimensions are 38 ft.×62 ft. The width is sufficient for two rows of stalls, and the stalls will run for $\frac{3}{4}$ the length of the barn, or 45 ft. (nearest multiple of 5 below the actual figure of $46\frac{1}{2}$). The total number of 5-foot stalls is thus 18. The barn will house 18 cows and 16 young cattle.

can be seen, the farm should be classed as a cow-calf beef farm provided that 15 to 45 percent of the acreage is corn. Where the corn acreage is outside these limits, the farm should be assumed to be a dairy farm with the milkhouse in the basement of the barn or an industrial milk operation without a milkhouse.

- Where land use indicates a beef operation, but a milkhouse is present, it is probable that the operation is a mixed one, producing both beef and milk, that a switch has recently been made from dairy to beef, and/or that the farm is run by a part-time operator. The last explanation is probably the correct one on farms where an unusually large amount of land is devoted to hay or pasture.

3. DETERMINATION OF CATTLE NUMBERS FROM LAND USE ANALYSIS

Once the nature of the livestock operation on any given farm has been established, it is possible to obtain an estimate of the number of cattle which can be maintained by the feed produced on the farm. The following steps are involved:

* Using the county crop-yield averages, calculate the total farm production under the categories of (*a*) hay and (*b*) fodder corn.
* It may be assumed that all the hay produced is stored on the farm and fed to the cattle. A

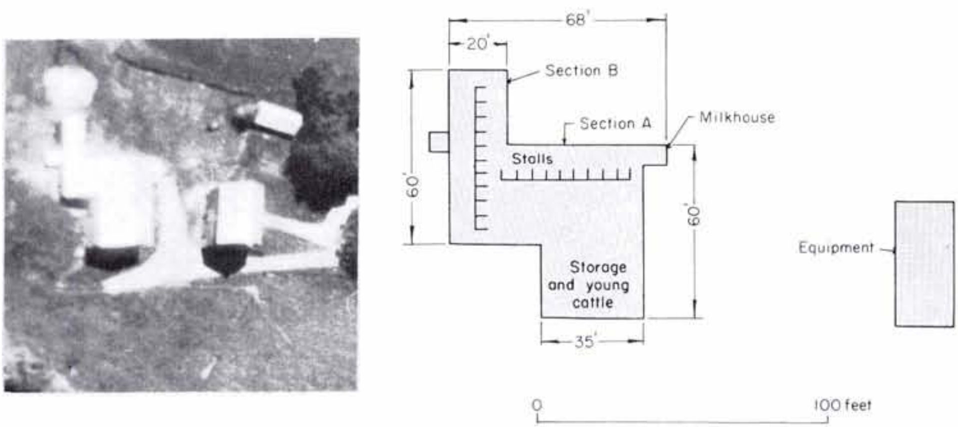
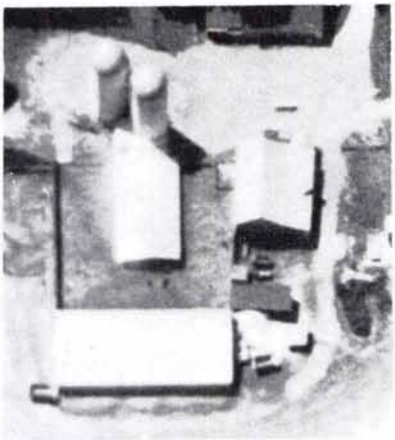
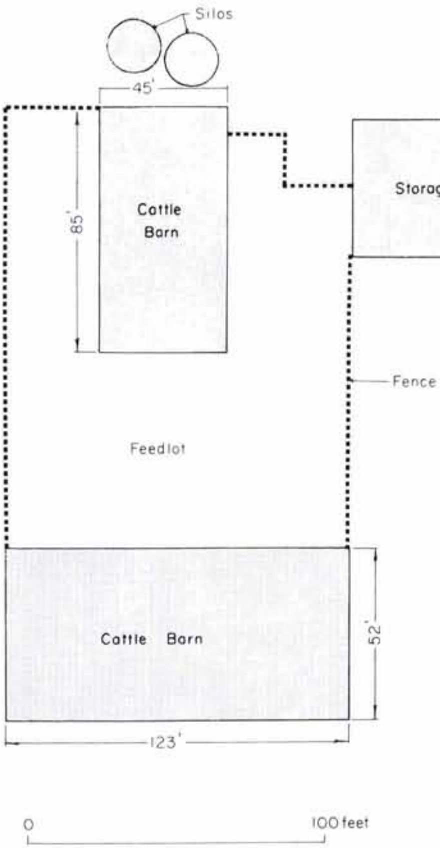


FIG. 4B. Housing in tie stalls in conventional barn modified by addition of an adjoining wing. In the original conventional barn (Section A), stalls run from the milkhouse towards the new addition to the barn (Section B). In the *L*-shaped Section A, the dimensions of the arm in which the stalls are located is 30 feet×38 feet. The width is thus sufficient for one row of stalls, and stalls will run for the entire length of the arm, except for the last three feet which is used as a passageway. Section B is used entirely for stalls except for a passageway at each end. As a stall width is 5 feet, Section A will contain 9 stalls, and Section B 10 stalls, for a total of 19, equivalent to the number of cows housed in the barn. The number of heifers and calves (at a ratio of 9 young animals to 10 cows) will be 17. The rectangular projection on the side of Section B would not be identified as a milkhouse because it is not accessible by road.

FIG. 5. Housing arrangements for beef cattle. 5A—Loose housing of steers in one-story enclosed barns. Barn dimensions are 45 feet×85 feet and 52 feet×123 feet for a total area of 10,221 sq. feet. Allowing 25 sq. ft. per steer, the number which can be housed is 408. The fact that the building on the right-hand side of the feed lot is used for storage and not for animal housing may be interpreted from the following features: the roof pattern indicates that the open side of the structure is away from the feed lot; the roadway on the open side indicates that the building is used for storage of machinery; and only a fraction of one side of the building is adjacent to the feed lot.





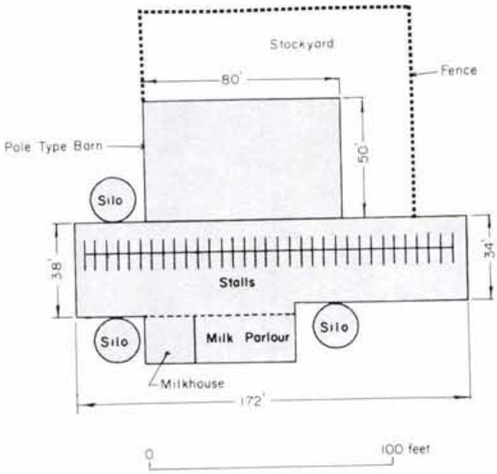


FIG. 4C. Housing in loose stalls in enclosed barn with attached pole type shelter. Dimensions of the enclosed section of the barn are 34 to 38 ft.×172 ft. As space for young animals and feed storage is available in the pole type section of the barn, it is assumed that the entire length of the enclosed section will be available for stalls. Presence of a milking parlor indicates a loose stall operation, such that the barn width will permit two rows of stalls. Allowing for a passageway at each end of the rows of stalls, the total number per row will be 32. Hence the barn will house 64 cows and 57 young cattle.

similar assumption, however, cannot be so safely applied to corn, much of which may be sold or used as grain rather than silage. To obtain a precise figure for the amount of silage which is used, one should measure, on the air photos, the silo dimensions and, using the values in Table 2, read off the number of tons of silage which it (they) can hold. This figure should be used rather than the total farm pro-

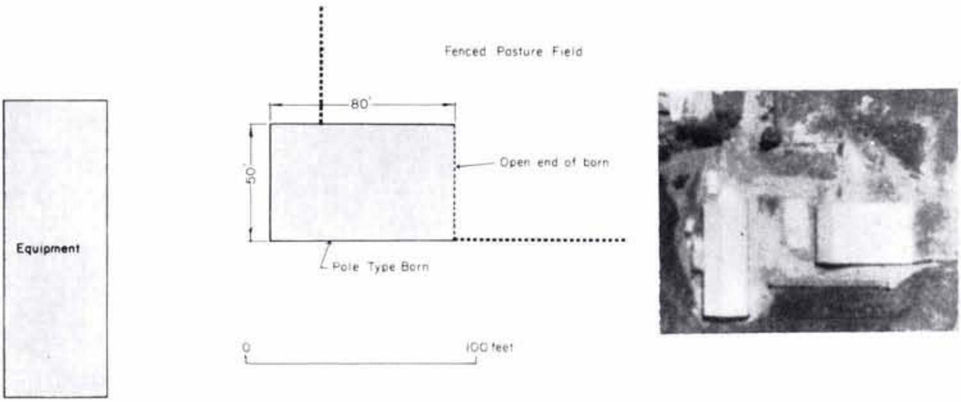


FIG. 5B. Cows and young cattle housed in conventional barn with tie stalls. Dimensions of the section of the barn used for cattle is 40 ft.×80 ft. The fact that the remainder of the structure is used for other purposes may be interpreted from the following features: it is a one-storey addition; and the only cattle-housing operation which would utilize an entire building of these dimensions is the loose-housing of steers, requiring an adjacent feed lot which is not present on this farm. The barn width of 40 ft. is sufficient for two rows of stalls, which run for 60 ft. of $\frac{3}{4}$ the length of the building. As each stall is 4 ft. wide, the total number of stalls is 30. The building therefore can house 30 cows and 30 young cattle.

duction of corn in instances where the latter figure is the larger.

- ★ From the values in Table 3 calculate the number of cattle which can be fed, during the six-month indoor feeding period,[4] using the hay and corn silage which are available.[5] In making this calculation, it is assumed for simplicity that any given animal is fed either hay or corn silage (which is perfectly possible) rather than a combination of the two (which is actually more likely). One works out the number of cattle which can be fed on the hay alone, and adds to this the number which can be fed on the corn silage.

At this stage of the procedure it is also necessary to assume that a cow-calf beef operation contains equal numbers of cows and calves, whereas a dairy operation will contain, on the average 5 calves and 4 heifers[6] for each 10 cows.

[4] It is taken as a working assumption that a farm needs one acre of improved pasture (or rough pasture equivalent) for each cow/calf combination or for each two steers. It follows then that any animals over and above the number that can be grazed on the available pasture will require "indoor feeding" for the entire year, and will thus need double the quantities of feed specified in Table 3.

[5] For this step in the methodology, it was found that the small grain production can be ignored. The reason is that many farmers either buy or sell some small grains, while commercial transactions involving corn silage and hay are negligible.

[6] In calculating feed requirements, all young animals are counted as heifers for the six-month indoor-feeding period (p. 59, Dairy Husbandry in Ontario).

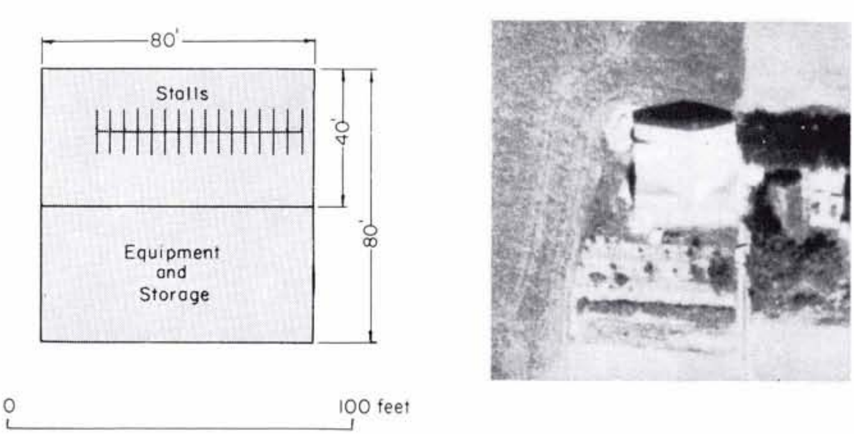


FIG. 5C. Loose housing of steers in pole barn. Dimensions of the barn are 50 ft.×80 ft. for a total area of 4,000 sq. ft. Allowing 98 sq. ft. per steer, the total number which can be housed is 41.

TABLE 2. TONNAGE CAPACITY OF SILOS[1]
Standard Silage Capacity Table for Estimating Approximate Farm Silo Capacity in Tons of All Silage Crops

Silo Height (Feet)	*Silo Diameter (Feet)*					
	14	*16*	*18*	*20*	*24*	*30*
20	54	70	80	110	158	248
25	73	96	121	150	216	337
30	96	125	158	195	280	440
35	119	156	197	244	350	550
40	145	189	239	295	423	663
45	171	224	283	350	503	788
50	200	261	330	407	583	913
55	230	301	380	468	673	1.060
60	260	341	430	529	760	1.190

[1] Source: Dairy Husbandry in Ontario.

TABLE 3. AVERAGE FEED REQUIREMENTS[1] FOR CATTLE FOR A SIX-MONTH PERIOD[2]

Type of Animal	*Pounds of Hay*		*Pounds of Corn Silage*
Dairy cow	3,960	*OR*	12,240
Dairy heifer	2,160	*OR*	6,480
Beef cattle, mature animal	3,780	*OR*	9,900
Beef cattle, yearling heifers and stockers	3,600	*OR*	9,514

[1] Values in the table were calculated by first obtaining the average liveweight for each type of animal and then allowing a daily food ration of 2½ lbs. hay or 6 lbs. corn silage for each 100 lbs. liveweight.

[2] In actual practice, the animals are normally fed both hay and corn silage. For purposes of determining the number of animals, however, it is satisfactory to assume that any given animal is fed *either* hay *or* corn silage.

4. DETERMINATION OF CATTLE NUMBERS FROM BUILDING ANALYSIS

Once the farm type is known, it is possible to determine fairly exactly the number of cattle that may be housed in a farm building of given shape and size, these dimensions being obtained by measurements made on the air photographs.

In a conventional barn, internally divided into stalls, the procedure involves estimating the number of stalls, assuming that they are laid out as indicated in the sketches (Figures 4, 5).

In such a conventional barn used for dairy cattle, one generally finds two rows of stalls, running 3/4 the length of the barn, provided that the barn width is 38 feet or more. With widths of 28 to 35 feet, one row of stalls runs the full length of the building. For an *L*-shaped barn, the same rules are applied to each wing separately. New additions to the barn may contain a full row of stalls even though no more than 20 feet wide. For such narrow additions, however, an allowance must be made for a four to five foot-wide corridor at each end of the row of stalls.

As the width of the stall used for a dairy cow is 5 feet, it is then quite simple to work out the number of stalls which any given barn contains. This number is then identical to the number of cows which can be housed. To obtain the number of young cattle (calves and heifers), one may assume that for each 10 cows there are 8 to 9 young cattle; these animals are kept in pens, in parts of the barn not divided into stalls.

Some newer one-storey barns use a free-stall system which permits two rows of stalls in a building only 25 feet wide. Dairy barns of this type can usually be identified on air photos, not only because of their shape and size but also because they invariably have an attached milking parlor if they are used to house dairy cattle (Figure 4).

For pole barns, in which dairy animals are not kept in stalls, the carrying capacity may be determined by assuming that cattle occupy 3/4 of the area of the building (the remainder being used for other purposes) and that within the area used for cattle, each cow will require 55 square feet.

On farms raising beef cattle, the carrying capacity of buildings is somewhat larger per square foot than on dairy farms. Thus, in a conventional beef barn, two rows of stalls may be found where the barn is 34 or more feet wide, and the stall width in a beef barn is only four feet. In almost all barns used for beef cattle, stalls only run 3/4 of the length of the barn.[7]

In pole barns,[8] the total area of the barn is used in the calculation. Ninety-eight square feet are allowed per steer or young cow.

In a few farms, beef cattle are housed loose, in barns without stalls. These barns may be of conventional type, with a pole type shelter built onto the side of the barn. Alternatively, they may be new one-storey structures over 40 feet wide. With this kind of housing where steers are kept, the number of animals may be determined by allowing 25 sq. ft. per head, the entire area of the barn being used in the

[7] In some beef barns, the animals are also housed in free stalls, rather than in tie stalls. This fact cannot be interpreted from aerial photographs, but the number of cattle which can be accommodated in this way is not significantly different from the number which would be housed in tie stalls.

[8] A pole barn used for raising beef cattle may usually be distinguished from a pole barn in a dairy operation since the latter is almost always associated with a milkhouse or milking parlor. Also, silos are more commonly found on beef than on dairy farms.

TABLE 4. TESTING OF COMPLETE METHODOLOGY BY SAMPLE AREA

Area	*No. of Farms in Area*	*Mean Error of Prediction Per Farm (in percent)*	*Actual Total No. of Cattle in Area*	*Predicted Total No. of Cattle in Area*
Wentworth	20	−0.11	Beef 674 Dairy 383	682 387
Wardsville	20	−1.3	Beef 1,084 Dairy 0	1,071 0
Owen Sound	20	−3.5	Beef 765 Dairy 698	730 685
Huron	21	−0.75	Beef 1,293 Dairy 254	1,282 258

TABLE 5. TESTING OF DIFFERENT SECTIONS OF THE METHODOLOGY

Nature of Analysis	*No. of Farms*	*Mean Error of Prediction Per Farm (in percent)*	*Standard Error of Prediction Per Farm (in percent)*
Building analysis only	81	−3.3	16.6
Land use analysis only	81	−3.6	14.3
Building and land-use analyses in combination	81	−1.4	6.1

calculation. In cow/calf operations, 3/4 of the area of the barn is assumed to be available for cows, and each cow is allocated 30 sq. ft.

The results of applying the given method of building analysis to the determination of livestock numbers in the farms of the four major study areas are given in Table 5.

STEPS THREE AND FOUR COMPARED

In most instances, the livestock estimate obtained from the land use analysis is very close to the estimate obtained using the building analysis. Where the difference is less than 8 cattle out of 100, the two values should be averaged. Where the difference exceeds this figure, the lower values should be accepted except that on farms with no hay and no silos, but in which the kind of barn and/or the presence of animal tracks and/or manure piles suggests that cattle are kept in the barns, the building estimate should be used.

In addition, where the building estimate is considerably larger than the land-use estimate, it is possible that the farmer's holdings are larger than was originally interpreted from the air photographs. In these instances, careful examination, on the photos, of the area within two or three miles distance from the home farm may permit the location of the missing acreage.

A few other special conditions also exist, which can be identified by air photo interpretation and which permit some further minor refinements in the estimation of the number of cattle. As these occurrences are quite uncommon, they are not discussed here.

TESTING OF THE METHODOLOGY

The results of applying the methodology to the determination of numbers of cattle within the four major study areas are as shown in Tables 4, 5 and 6. It will be noted that the mean error of prediction is less than 4 percent, even where only one of the two elements of the methodology is used. Utilizing both land-use and building estimates in combination, the mean error is reduced to less than $1\frac{1}{2}$ percent where the standard error for any given farm is approximately 6 percent, being slightly higher for dairy than for beef farms.

TABLE 6. TESTING OF COMPLETE METHODOLOGY BY FARM TYPE

Farm Type	*No. of Farms*	*Mean Error of Prediction Per Farm (in percent)*	*Standard Error of Prediction Per Farm (in percent)*	*Actual Total No. of Cattle in Area*	*Predicted Total No. of Cattle in Area*
Beef	52	−1.9	5.9	3,816	3,765
Dairy	29	−0.5	7.3	1,335	1,330

Conclusion

Using air photo interpretation alone, it is possible to determine with a high degree of accuracy what kind of cattle-raising operation is being practiced on farms of Southern Ontario, and how many cattle are being kept on each farm.

The exact application of the described procedures in other parts of North America would probably not give an equivalent degree of success as other areas may have their distinct cattle feeding and housing systems. Nevertheless, the general approach that has been applied in the present study in Southern Ontario can be utilized everywhere to permit the precise evaluation from air photos of a number of important elements in the farm economy. The ordinary black-and-white photography can reveal a vast amount of new information, provided that the air photo user is adequately informed about the phenomena he wishes to interpret.

Meetings Schedule

Mar. 2–4. Workshop—Color Aerial Photography in the Plant Sciences and Related Areas. Univ. of Florida. Mr. Gerald G. Norman, Box 1269, Gainesville, Fla. 32601.

Mar. 7–12. Annual Convention, Washington Hilton, D.C. Mr. Roy Mullen, 6202 Tanglewood Court, Springfield, Va. 22152.

Apr. 17–25. Photo Expo 71, McCormick Place, Chicago. ASP, SPIE, SPSE, SMPTE, PRS.

May 17–21. 7th International Symposium on Remote Sensing of Environment, Ann Arbor, Mich. Center for Remote Sensing, Willow Run Labs., P.O. Box 618, Ann Arbor, Mich. 48107.

June 16–18. Image Deformation Conference, Ottawa. Mr. T. J. Blachut, Photogrammetric Research, Physics Division, National Research Council, Ottawa 7, Ontario, Canada.

Sept. 7–11. Fall Technical Meeting and Seminar on Computational Photogrammetry. San Francisco Hilton, Calif. Mr. J. E. Chamberlain, USGS, 345 Middlefield Road, Bg. 3, Rm. T109, Menlo Park, CA 94025.

Oct. 21–23. Photogrammetric Surveys & Mapping. Univ. of Missouri. Mr. Charles H. Croom, Route 1, Box 159, Rolla, Mo. 65401.