A MEASURE OF AGRICULTURAL PRODUCTIVITY

USING RS TECHNIQUES

A MODEL TO PROVIDE A MEASURE OF AGRICULTURAL PRODUCTIVITY USING REMOTE SENSING TECHNIQUES

by

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This thesis provides a means of measuring the type and number of livestock on a given farm in southern Ontario using as a data base aerial photographs of medium scale. The feasibility of making such measurements is shown to be an extension of past work in the field of agricultural air photo interpretation. The methodology is presented in the form of a model. The inputs from aerial photographs are crop acreages, building type and dimensions, and silo sizes. Average yields in each study area, in combination with crop acreage gives feed available. A comparison is made between feed weight and housing space available and required feed weights and stabling facilities (taken as constants in southern Ontario) to support cattle of a given type. This comparison technique, within the model, yields an output of farm type and actual numbers of cattle. The accuracy of prediction so obtained is high and is independent of the location or attributes of the widely spaced sample areas.

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CHAPTER I

INTRODUCTION

1.1 The Problem

Two basic assumptions provide the foundation upon which this study is built. The first is of a twofold nature.

Geography will likely continue in the future to attempt to answer academic and practical questions with regard to agricultural land use and the potential productivity of agricultural land. In order to test hypothetical deductive constructs designed to assist in the derivation of answers to these questions, various data concerning agricultural land use and productivity must be collected.

The voluminous literature in geography on agricultural land use theory and data collection is left to provide the defence for this assumption.[1]

The second assumption follows from the first: the use of aerial photographs, a remote sensing technique,[2] is a useful means of collecting data on agricultural land use.

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[1]Some of this pertinent literature is listed in the Bibliography of this study in the section on agricultural land use.

[2]As defined by E. Moore and B. Wellar, "Urban Data Collection by Airborne Remote Sensor", J. Amer. Inst. of Planners, Jan. 1969.

Haggett has stated, with reference to model building, "air photographs mirror reality"[3]. "The faculty of being a mirror of reality removes subjectivity that could be contained in the reports of field observers."[4] Further, "aerial survey techniques are characterized by speed and ease of collection of data".[5]

The thesis put forward in this study is that using data obtainable from aerial photographs, it is possible to construct a workable model capable of predicting, to a high degree of accuracy, the type and number of cattle on a given farm in southern Ontario. The type and number of livestock then serve as specific measures of agricultural productivity, or land use intensity.

1.2 The Model

Since this research has as its purpose the development of a model, it is appropriate to establish an adequate definition of "model" for use in the context of this study.

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[3]P. Haggett, Locational Analysis in Human Geography, London: Edward Arnold, 1965, p. 20.

[4]R. A. Ryerson, Toward a Model to Predict Livestock Carrying Capacity Using Aerial Photographs, B.A. Thesis (unpub.), McMaster University, Hamilton, Canada, 1969, p.2.

[5]A view expressed by M. Goodman in "A Technique for the Identification of Farm Crops on Aerial Photographs", P. Eng. 1959. Other writers have made reference to this same feature, see the section on Aerial Photographs in Agriculture in the Bibliography.

Such a definition is given by Meadows. He states a model is a "pattern of symbols, rules and processes regarded as matching in whole or in part an existing perceptual complex".[6] One must note that this definition has been selected from many available.[7]

Subjectivity on the part of the model builder must be recognized. In developing any model or "pattern", one must abstract material from the real world. Further one must decide the weighting of values and how these various weighted values may be quantified. The decision of what material is relevant and the weighting of values are both largely subjective.

Other characteristics of models are the following: "simplicity", which facilitates easy understanding, "representativity", in that the model represents the "total range of implications", and comprehensiveness "for the model must represent the system under study".[8]

1.3 The Nature of Photo Interpretation

At this time it is appropriate to present a further qualification of the study at hand. This qualification relates to the definition of interpretation, "the act of examining photographic images for the purpose of identifying objects and judging their significance".[9] Some

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[6] Meadows, "Models, Systems and Science", Am. Soc. Rev., Vol. 22, p. 6.

[7] Other definitions are given in R. Chorley and P. Haggett, (Eds.) Models in Geography, London: Methuen, 1967.

[8] ibid. p. 23.

[9] R. N. Colwell (Ed.) Manual of Photographic Interpretation, Washington: American Society of Photogrammetry, 1960, p. 853.

of the studies in the past[10] have simply tried to count cattle in the fields. These studies have thus used a procedure more properly defined as "photographic reading, ... an elementary form of photographic interpretation, usually limited to simple identification and description of objects imaged in photographs".[11] This study will attempt to arrive at cattle numbers through photographic interpretation.

1.4 Previous Work

The development of such a model represents an extension of past work in the field of air photo interpretation of agriculture. This may be demonstrated by a short discussion[12] in chronological order, of pertinent literature available at the time of writing.

The earliest meaningful paper relating to remote sensing in agriculture dates from the year 1951 when Foster published a study entitled "Field Use of Aerial Photographs by Geographers".[13] This attempt at bringing together the geographer and air photo interpretation provided a basis upon which many other studies developed.

In 1957 Brunnschweiller introduced the concept of comparative

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[10] See for example R. N. Colwell in Remote Sensing with Special Reference to Agriculture and Forestry, Washington: National Academy of Sciences, 1970, pp. 209-219.

[11] R. N. Colwell (Ed.) op. cit.

[12] The following draws from a similar review by this author in an earlier study. It has been modified with regard to emphasis, changed in format, and considerably expanded for the purposes of this study.

[13] F. W. Foster "Field Use of Aerial Photographs by Geographers", P. Eng., 1951, p. 771.

air photo interpretation in agriculture. He illustrated how "seasonal changes"[14] such as crop growth, affected relative ease of identification of crops. Dill expanded this by presenting a method of measuring land use acreage changes over time.[15] He concluded that "use of air photo comparison methodology provides a means of obtaining data on agricultural land uses for economic analysis, with a minimum expenditure of funds and a small number of professional personnel, in a relatively short time".[16]

The most notable of the earlier studies was that of Goodman. She attempted to develop a method based on tonal and textural variations that would yield "both speed and accuracy in field mapping"[17] of farm crops. She noted that in the "early intervals of growth"[18] limitations on accuracy exist for all of the "spring planted crops have identical photo appearance".[19]

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[14] D. Brunnschweiller, "Seasonal Changes in Agricultural Pattern - a Study in Comparative A.P.I.", P. Eng., 1957, p. 131.

[15] H. W. Dill, "The Use of the Comparison Method in Agricultural A.P.I.", P. Eng., 1959, p. 49.

[16] ibid.

[17] M. S. Goodman, "A Technique for the Identification of Farm Crops on Aerial Photographs", P. Eng., 1959, p. 131.

[18] ibid. p. 135

[19] ibid.

Air survey techniques were applied in conjunction with detailed ground control by Kreuger[20] and Putnam[21].

The possible uses of aerial photography for "farm management"[22] were outlined by Nobes in 1958. He suggested that non-farm areas could be distinguished from active farms by the presence of active barnyards identified by the presence of manure piles, etc. Using a larger sample he expanded this topic in 1961[23]. More detailed keys for identifying "land holding types"[24] by "farmstead qualities"[25] for application to rural planning were recently introduced by Peplies.

The years 1959 to 1961 saw the development of new imagery, color and infrared, in remote sensing in agriculture. Colwell noted both the uses and limitations of color imagery in agricultural studies.[26] In the former category he included "crop identification, crop maturity, disease, crop vigor, weeds, mapping agricultural sort types, ... and

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[20] R. Kreuger, "Study of Changing Land Use in the Niagara Fruit Belt 1956-57", Royal Geog. Instit. Pt. 2, 1959, pp. 38-140.

[21] R. G. Putnam, "Study of Changes in Rural Land Use Patterns on Central Lake Ontario Plain (1960), Can. Geog. 1962, p. 60.

[22] K. Nobes, "Use of Aerial Photography for Farm Management and Land Economics Research", Land Economics, 1958, p. 271.

[23] K. Nobes, "Use of A.P.I. in Agricultural Land Economics Research", Land Economics, 1961, p. 321.

[24] R. N. Peplies, "Farms, Rural Planning and Remote Sensing", Papers, 35th Annual Meeting, Amer. Soc. of Photogrammetry, Washington, 1969, p. 245.

[25] ibid. p. 254.

[26] R. N. Colwell, "Some Uses and Limitations of Aerial Color Photography in Agriculture ", P. Eng., 1960, p. 220.

ground water estimates".[27] The limitations are primarily a result of the narrow limit of exposure resulting in fewer hours of potential coverage, and the costs involved in processing and storage.[28]

Following the introduction of the "new" techniques using color and IR imagery some authors doubted their value and called for refinements. For example Findley stated: "thermal imagery is a valuable source of supplementary information, but as yet cannot be considered as a substitute for visual air photo interpretation".[29]

Since 1961 these more sophisticated techniques have been expanded and refined in both use and level of sophistication by such researchers as Gates[30], Estes[31], Philpotts and Wallen[32] and Colwell[33]. Indeed a a recently published book deals exclusively with Remote Sensing with

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[27] ibid.

[28] ibid. p. 221.

[29] V. P. Findley, "Seasonal PI of the Cultural Landscape", 19th Internat. Geog. Cong., Stockholm, 1960, Abstracts, 168, 1960.

[30] P. Gates, "Characteristics of Soil and Vegetated Surfaces to Reflected and Emmitted Radiation", Proc. 3rd Symp. on R.S. of Environment, Ann Arbor, Mich.: IR Physics Lab, 1965.

[31] J. Estes, "Some Applications of Aerial IR Imagery", Annals AAG, 1966, p. 673.

[32] L. Philpotts and V. Wallen, "IR for Crop Disease Identification", P. Eng., 1969, p. 1116.

[33] R. Colwell, "Spectroectric Considerations Involved in Making Rural Land Use Studies with Aerial Photography", Photogrammetria, 1965, p. 15.

Special Reference to Agriculture and Forestry.[34]

These techniques[35], although valuable, will not be discussed here, for this study deals primarily with data obtainable from the interpretation of panchromatic aerial imagery.[36]

Others believed one could improve on uses being made of available, and inexpensive panchromatic imagery. The most notable contribution in the interpretation of standard black and white imagery was made by Goodman.

In 1964 Goodman set out "Criteria for the Identification of Types of Farming" using sequential panchromatic coverage of unspecified scale. The criteria set out were:

"1. farmstead features such as barns, granaries and silos

2. crop associations

3. uses made of corn and hay".[37]

Applying these criteria to dairy farm identification she stated "approximately half of the cropped land is used for hay and pasture. Corn and oats; or corn, oats, and a cash grain occupy the remaining

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[34] J. R. Shay, (Ed.) Remote Sensing with Special Reference to Agriculture and Forestry, Washington: National Academy of Sciences, 1970.

[35] Some of these techniques and their application to this study will be discussed in Chater VII.

[36] Although the bulk of photography is black and white, one area's coverage was in color.

[37] M. S. Goodman, "Criteria for the Identification of Types of Farming on Aerial Photographs", P.Eng., 1964, p. 984.

cropped land about equally."[38]

"On farms that combine hog raising with beef fattening, corn and hay account for half or more of the cropped land. The remainder is used for two or three crops such as oats, soybeans, rye, barley, rape, and rotation pasture."[39]

In that no deductive constructs explaining the crop association criteria were presented it has been assumed that they were derived perhaps by the simple method of observation of empirical evidence drawn from her sample area.

Her assumption that these criteria are valid for the "Great Lakes Region"[40] has not, however been suggested by the earlier research by this author[41]. It would seem, in this case, that a logically deduced technique of farm type identification based on required feeds for each type of operation is preferable to the empirical approach taken by Goodman. Only in this way may one rationally approach the problem of predicting the geographical extent of the validity of a model.

Schepis, in a more recent paper, considers Goodman's earlier studies of crop identification, and supplements them by the addition of two new techniques. These are a method of forecasting yields, and

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[38] ibid. p. 985.

[39] ibid.

[40] ibid. p. 990.

[41] R. A. Ryerson, op. cit. p. 52.

the development of a computer program to handle the data analysis. The purpose was to "determine whether cropping practices could be observed, timed, and evaluated by photogrammetric methods to aid agricultural extension workers in making valid generalizations regarding current farm practices".[42] He concluded these practices could be determined.

1.5 Previous Work By the Author

An earlier study by this author tried to go "beyond the work of Schepis, since the measurement of livestock carrying capacity is a next logical step following after the identification of cropping practices".[43] The model developed was based entirely on crop combinations and thus failed to include a number of variables of a subtle nature. Nevertheless conformation was provided for its basic assumption, that farmers grow feed in accordance with "feed requirements for dairy and beef cattle ... (which) ... are set out separately, fully, and rigidly in the Ontario Department of Agriculture's publications on dairy and beef husbandry".[44] It was then assumed, less realistically, that on each farm the ages and breeds for dairy and beef cattle would

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42 Schepis, L. "Time Lapse Remote Sensing in Agriculture", P.Eng., 1968.

43 R. A. Ryerson, op. cit. p. 7.

44 See Bibliography - Section on Agronomy.

be the same as those for the county as a whole.[45]

Thus each farm was assumed to have:[46]

FOR BEEF			FOR DAIRY		
Calves	-	14%	Calves	-	31%
Cows	-	14%	Cows	-	54%
Yearlings	-	17%	Yearlings	-	15%
Steers	-	55%			

The weight of feed needed to support 100 cattle of the age categories above was determined using average yields in the study area. The weights were transformed to acreage equivalents. These acreage figures were then expressed as a percentage of the total acreage producing feed. Eighteen theoretical acreage breakdowns resulted from the above transformation. These acreage breakdowns were placed on a triangular diagram (Fig. 1).

A first order nearest neighbour technique was employed to determine which of the theoretical feeding systems was probably being used on a given farm. Actual acreage was compared to the acreage required to support 100 cattle. This resulted in

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[45]Occurrences in the county were derived from Agricultural Statistics for Ontario, 1967, Pub. #20, Ont. Dept. of Ag., Toronto.

[46]R. A. Ryerson, op. cit., Table 1, p. 24.

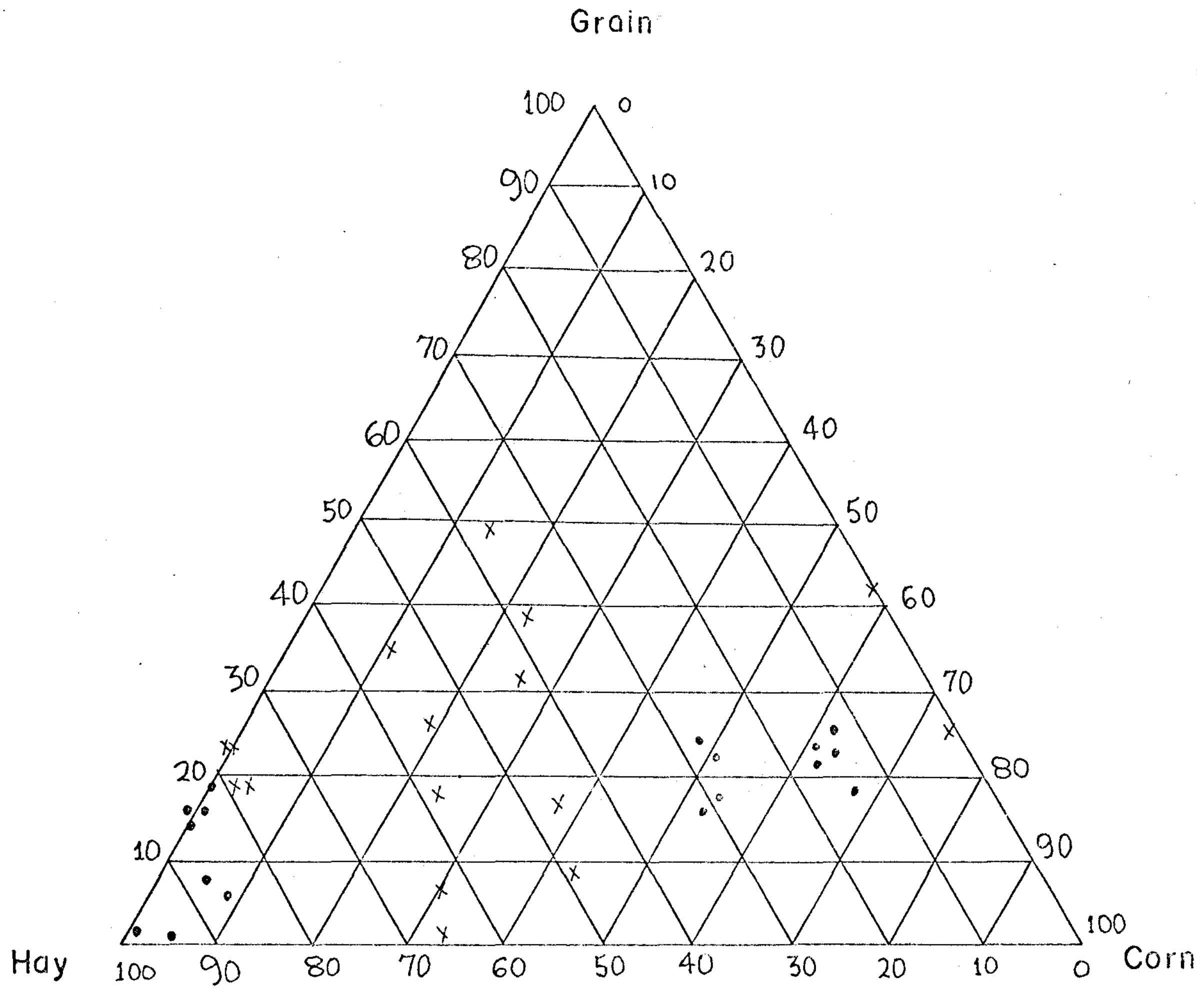

Fig. 1

SUGGESTED FEEDING[1]: HAY, CORN
SMALL GRAIN ACREAGE RATIOS
BY %

x = Dairy

• = Beef

[1] Derived using yield data from Wellington Co.
R. Ryerson, op.cit., p. 44.

$$X = \frac{\frac{\text{hay - corn - grain}}{\text{actual acreage}}}{\text{theoretical acreage required to support 100 cattle}} \times 100^{*}$$

*where X = the maximum number of cattle the farm could support with the given acreages.

The accuracy of the model (given below) when it was applied to the actual numbers of cattle in a real world situation indicates that there is some merit in the model. The standard errors, however, show inherent inaccuracies in the model. Thus the model produced can only be considered as a beginning.[47]

RESULTS OF THE APPLICATION OF RYERSON'S[48] 1968 CROP MODEL

	Mean Accuracy	Standard Error
Dairy	80%	18%
Beef	94.6%	27.1%

The problem lies in the simplistic nature of the assumptions concerning cattle ages and feeding systems. The assumptions concerning cattle ages on beef farms are especially weak.

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[47] It must also be noted that the model was to predict maximum capacity. In that this maximum value is unknown, the accuracy level may be higher than indicated.

[48] R. A. Ryerson, op. cit., p. 52 and p. 53.

Many farms feed only steers, while others feed only calves and cows. The very general groupings set out by Goodman (beef and dairy) and used in the earlier work by this author cannot therefore be considered an adequate framework within which to begin detailed analysis.

The identification of the model's limitations, some of which are mentioned above,[49] have however provided a link with the more general studies of the past and have pointed to the development of methods for more detailed analysis of panchromatic aerial imagery.

1.6 Summary

The model presented in this study has reconsidered the assumptions concerning feeding systems and cattle ages. Further, another important feature, farm buildings, has been included.

In this way the application of techniques of interpretation of panchromatic aerial photographs in agriculture is moving ever from the more general to the more specific.

In summary the present study has as its objective the preparation of a model that will serve to predict the type and number of livestock on individual farms using, as a source of data, panchromatic aerial imagery.

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[49] ibid. Chapter VII.

CHAPTER II

THE VARIABLES

2.1 Introduction

Following from the thesis put forward on page 2 of this study, the variables which are of interest are those factors that influence the type and number of livestock that may be raised on a given farm. Further, these variables, or factors, must be readily measured or interpreted from panchromatic aerial imagery.

Involved in the measurement and/or interpretation of these factors is the consideration of scale of imagery required. The size of the variables or features being measured, in conjunction with degree of precision of the measuring devices, determines the required photo scale. The discussion of scale will therefore follow consideration of the important variables influencing the number of livestock that could be carried per farm.

2.2 External and Internal Constraints

Livestock raising may be thought of as a system operating within a framework of two major constraints: the provision of specific foods in sufficient quantities to enable the livestock to live and maintain a desirable level of production, and second, the provision of adequate shelter in order that the livestock may survive the rigours of the winters in southern Ontario[1].

Other major constraints also exist. The controls of the marketing system, and cattle breeding are, however, assumed to be reflected in the specifications used for the provision of adequate food and shelter.

Within the system are what may be called internal constraints. These may be defined as those options available to the farmer within the framework of the external constraints. These internal constraints may, however, result in an increase or decrease in the number of cattle carried per acre. One such control is level of mechanization. The extent to which a given farm is mechanized is generally positively related to the degree of efficiency.[2] Also related to efficiency are storage capacity (in bunker silos, silos, granaries, etc.), stable facilities, and cropping techniques.

Implicit in the above is a factor of choice. A farmer may choose to operate in a number of different ways within the external framework set out above. Therefore one may regard the farmer's attitude as a factor affecting carrying capacity.[3]

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[1] Dairy Husbandry, p. 25 and Beef Husbandry, p. 13 & pp. 19-20.

[2] A. G. Teskey, "The Economics of Feed Storage", O.S.G.I.A., 1967, p. 202.

[3] F. G. Fliegel and J. E. Kivlin, "Farm Practice Attributes and Rates of Adoption", Social Forces, 1962, p. 364.

--------, "Orientations to Agriculture: A Factor Analysis of Farmer's Perceptions of New Practices", Rural Soc., 1968, p. 127.

However, the purpose of this study is to develop a means of measuring what is present. No explanation of why, or how, a phenomenon occurs need be given. Therefore the reasons for choosing one method of farming over another, or the inherent merits or faults of any given method, need not be considered. The farmer's personality, as a separate variable, may be ignored except to the extent that it will be reflected in his choice of crops, type and method of farming, storage facilities, and stable design. These elements in turn are unimportant only in their effect upon production. In a like manner level of mechanization is assumed to be reflected in the farmer's mode of operation, since sophisticated equipment will generally result in different crop combinations, larger fields and often larger farms with attendant larger buildings.[4]

Environmental controls are, like implements, considered to be an internal constraint. These controls are not considered to be unimportant[5], but the farmer is assumed to adjust to these environmental controls. For example one generally finds very poor land used as rough pasture. Heavy clay soil is more likely to be used as a hay or pasture field rather than as a corn field.[6] Further it has been assumed that

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[4] A. Livingston, "My Farm Programs", O.S.C.I.A., 1968, p. 163.

[5] In the earlier study by this author the effect of the environment did not seem markedly important, R.A. Ryerson, op. cit., p. 70-72.

[6] E. F. Bolton, "Soil Management for Cash Crops", O.S.C.I.A., 1968, p. 208.

environmental controls are reflected in the crops grown in the study areas, and in the yields of these crops.[7]

The average yield is assumed to approximate the expected yield. In this way one may compensate for over-production causing surplus, and under-production resulting in a feed shortage, in a given year. If dealing with older photography (as is the case in this study) actual yield values as given in Agricultural Statistics for Ontario may be used.

If the above assumptions are indeed valid then the accuracy of the model should not be affected by the removal from consideration of physical or environmental controls.

Up to this point in the discussion a number of factors have been suggested. Those left for consideration after the discussion above are the external controls, cropping combinations, and stable facilities. No specific details have been presented.

The external controls will vary with type of operation. A dairy farm, for example, will vary considerably in cropping combinations and stabling needs from a steer feeding operation.[8] The latter, in turn, will require less feed per animal and different stabling arrangements than for a cow-calf operation.

In short, feeding practices and the resulting crop combinations

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[7]County yield data with relation to broad climatic variations.

[8]These differences are fully outlined in Chapter IV of this study for crops, and Chapter V for buildings.

depend on the size and age of dairy cattle, and on the size, age and purpose of beef cattle.[9]

2.3 The Importance of Crop Combinations

In that "feed costs represent 50-60% of the cost of producing a pound of beef or pork"[10] the use of feeding systems as a basis of measuring productivity is easily defended. Crops present are assumed to be related to the feeding systems used on a given farm. The remaining 40-50% of the production costs relate to land and equipment costs, and capital investment in buildings.[11] Buildings and crop combinations would appear to be the factors that affect livestock carrying capacity, and which, if measured, could yield an indication of the number of cattle on a given farm.

It should suffice to outline here the basic assumptions drawn from agronomy. In this way the reader may be made aware of the emphasis on the technique of moving from the known (readily seen or measured on the photography) to the unknown by way of logical inferences based on a thorough knowledge of agronomy. The following chart lists some of the inferences used in this study[12] at the outset. More complicated

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[9] Beef Husbandry, op. cit., p. 2-4; and Dairy Husbandry, op. cit.

[10] J. D. Curtis, "Crop Recommendations for Eastern Ontario", O.S.C.I.A., 1967, p. 165.

[11] Taken from various papers and governmental publications concerning care and management of livestock farm planning, and equipment costs. See Bibliography, Section on Agronomy.

[12] The inferences listed in the chart are in part drawn from the earlier study by this author, R.A. Ryerson, op. cit., p. 17.

CHART 1

INFERENCES DRAWN FROM THE INTERPRETATION OF PANCHROMATIC AERIAL PHOTOGRAPHS OF AGRICULTURAL LAND USE

KNOWN FROM PHOTOGRAPH	ASSUMPTION
1. No silos (vertical or bunker)	- no corn, hay or grain used as silage
2. More grain crop than would be required for feed	- some grain is sold as a cash crop
3. Pasture is improved pasture	- assume it yields 60% of what dry hay yields in the same area[13]
4. Pasture is rough pasture	- assume it yields 30% of what the dry hay yield is in the same area
5. All land is hay and pasture	- assume all of this is fed and all concentrates and grains are purchased
6. All land is in corn and silos are present	- assume some corn is used as grain and the rest is used as ensilage
7. Appearance of building and stable yard[14, 15]	- assume appearance related to use. This concept is fully developed in Chapter V as the Building Model

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[13] J. D. Curtis, op. cit., p. 166.

[14] For a discussion of keys to identify active farmsteads see R. W. Peplies, op. cit.

[15] Farm boundaries provide a limitation on the operation of the

postulates are developed within the models put forward in Chapters IV and V.

Crop combinations present have been recognized as a key to type of livestock, and type of feeding system used on a given farm. This has been related to the interpretation of actual livestock numbers in the earlier work by this author.

If one knows the nature of the livestock, the feed weight required per animal, and the acreage of each crop on the given farm, adding data on the yield per acre in the area in which the farm is located will make it possible to calculate the number of cattle which the farm can provide with feed. Unfortunately accurate information of this kind is difficult to obtain.

One method of determining yields is to use control fields, as did Schepis.[16] Other methods using more sophisticated imagery have

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method presented in this study. Farm boundaries generally follow the earlier rectangular surveys by lot and concession in southern Ontario. The delimitation of farm boundaries has been discussed by Goodman and other authors mentioned above.

The orientation of farm lanes, animal pathways, etc., give the initial keys to the separation of discrete units. This author suggests that one may use the pattern of cultivation and harvest as identified by Wood to separate out farm units held by different farmers. Similar patterns in farms adjacent to, or across the road from, each other may be grouped in this manner. The presence of houses not apparently joined to the farm operation, or the presence of farm buildings not apparently used to house livestock on farms with roughage crops, are other indicators of farms that are separate from the main farmstead.

Further research is needed to provide concise keys to separate out all land parcels into farm units. The methods presented above are not workable in all cases. Residual parcels of land of small size have occurred. These were, in most cases, parts of larger farms held by farmers outside the flight line.

[16]The difficulty of obtaining this information, in conjunction with the desire to remove as much ground control as possible has resulted in the removal of the use of this technique. L. Schepis, <u>op. cit.</u>

been rejected for the purposes of this study. For lack of an alternative, therefore it was decided simply to use the average yields in the county[17] over several recent years. Comments on the validity of using such generalized yield data are made on page 71 of this study.

The next step is to discuss the particular feeding systems, and specific building types and uses and their relationships to livestock numbers.

2.4 The Importance of Farm Buildings

Housing requirements, like feeding requirements, are related to type, size, age, and purpose of the animals to be housed.[18] Particular building types are associated with particular uses,[19] while barn size may be associated with the housing of a given number of cattle. Measurement of building size, and notation of design, would therefore seem to provide a clue to livestock carrying capacity. The discussion in Chapter V, which is concerned with the development of a predictive model of livestock numbers based on building capacity, is founded on this assumption.

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[17] Agricultural Statistics for Ontario, Pub. 20, Ontario Department of Agriculture and Food, Queen's Park, Toronto.

[18] Beef Husbandry in Ontario, op. cit., pp. 44-47.

[19] ibid., p. 44.

2.5 Photo Scale

The photographs available were at a minimum scale of 1:12000, the scale selected for crop identification.[20] The instruments available to the author were capable of measuring to an accuracy of 1/500 inch. On a scale of 1:12000 the accuracy of measurement permitted is ±2 feet.[21] Looking ahead to page 58 one may see that measurements must be accurate within two feet for cattle stall estimates. Other important measurements are also differentiated in terms of four or five feet.

At a scale of 1:12000 the separation of corn, grains, hay, and pasture is a simple matter.[22] With the use of more sophisticated measuring devices, photographs with good resolution and a much smaller scale may well be adequate. Therefore, the available photography is considered to be very adequate for the purpose of this study.

2.6 Summary

In summary the factors affecting the numbers of livestock on any given farm may be considered to be the following: crop combinations employed on the farm and resulting weights of feed available,

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[20] Used for crop identification research carried out by H. A. Wood, Department of Geography, McMaster University, Hamilton.

[21] This figure was determined using determination of distances in reality from aerial photographs from E. Avery, Interpretation of Aerial Photographs (2nd ed.) Minneapolis: Burgess Pub. Co., 1968, p. 38.

[22] See for example some of the articles reviewed in the preceding chapter, "The Problem", notably Goodman (1959), and Schepis (1968).

housing capacity of buildings, the storage capacity of silos, and type of operation. These may, or may not, be in balance one with another. It is the contention of this author that all other factors one may consider are either reflected in, or lead to, the four factors listed above.

CHAPTER III

THE STUDY AREAS AND THE DATA COLLECTION

3.1 Introduction

Clearly the procedure developed in this study could be worked out in areas relatively homogeneous with respect to environmental controls, age and knowledge of individual farmers, level of mechanization, size of farm unit and type of operation. However, if this had been done there would be no way of checking on the validity of the assumptions that a farmer adjusts to environmental controls and that the procedure is applicable to farm units of the various descriptions presented above. If the models to be developed are tested and prove accurate on such a varied base the assumptions made concerning the internal and external factors may be accepted with more confidence.[1]

When one is selecting study areas one must seek an adequate variety and intermixture of the external, or primary factors listed on page 14: type of operation, cropping associations, storage facilities, and buildings. In addition the testing of the feasibility of measuring livestock production as a winter sideline of a cash crop farm makes it desirable that mixed "cash-beef" farms also be included in the sample.

[1] One might argue that these controls have, in effect, cancelled each other out in the particular area, southern Ontario, in which the model is tested.

3.2 The Study Areas

Three such areas were selected for general studies in airphoto interpretation in agriculture.[2] A fourth was selected for bean disease detection.[3] These are referred to as Owen Sound, Hamilton, Wardsville and Huron respectively. The locations are mapped in Figure 2. Coverage for the first three was procured in the summer of 1967, using panchromatic film, minus blue filter, and at a scale of 1:12000. Coverage for the Huron area was procured in August 1968, using a variety of imagery, filters and scale. The imagery used for this study was Ektachrome 8442 visible color film with no filter at a scale of 1:8400.[4]

The attributes of each sample area may best be presented by a short discussion of each area.

The Owen Sound area tends to droughts in summer, with shallow soil and scarce well water.[5] Dairy cattle producing either fluid or industrial milk tend to be of primary importance.[6] Beef cattle do not appear to be important in the area adjacent to Owen Sound.[7] Some farms

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[2]Made available by H. A. Wood.

[3]L. Philpotts and V. Wallen, op. cit. The color photographs of larger scale (1:8400) used in this study were originally taken for research in bean disease carried out in 1968 by Philpotts and Wallen.

[4]ibid. p. 1117.

[5]L. Chapman & P. Putnam, p. 195.

[6]Ag. Statis., op. cit. pp. 95-96.

[7]See Appendix B, Raw Data, to note the wide variations in the Owen Sound Area.

were found to be influenced by land speculation, (see Chapter VI). Farm size varies greatly. Few buildings are new, and buildings are rarely of a new design. Generally the level of efficiency is the lowest found in the study areas. For the county (Grey) as a whole, fodder corn yield in 1967 averaged 11.8T/ac.[8] and hay yield averaged 2.7T/ac.[9].

The Hamilton area (Wentworth County) is overlain by drift of varying depths. Some areas of sand are dry. As in the Owen Sound area dairy cattle tend to be of prime importance[10], but the Hamilton area is distinct in that it is a major urban area. It may be that nearness to the city causes farmers to farm in the inefficient manner suggested by Sinclair.[11] Farm size and carrying capacity vary greatly. Some new buildings of a modern design have been constructed, but these represent more the exception than the rule. In 1967, in Wentworth County, fodder corn yield was 13.1T/ac. and hay yield averaged 2.96T/ac.[12]

The Wardsville area (Elgin County) is generally an area of sandy surface material overlying clay. Productivity varies greatly.[13] The area is primarily one of a cash crop emphasis, with little dairying.

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[8] Ag. Stats., op. cit. p. 52.

[9] ibid. p. 58.

[10] ibid. pp. 95-96.

[11] R. Sinclair, "Von Thunen and Urban Sprawl", Annals A.A.G., 1967.

[12] Ag. Stats., op. cit. p. 52 and 58 respectively.

[13] L. Chapman and P. Putnam, op. cit. p. 238.

Feeding beef for weight gain in conjunction with cash crop farming is the dominant livestock operation found in this area. As indicated in Appendix B buildings vary greatly. In 1967 fodder corn yield averaged 13.6T/ac. and hay yield averaged 2.64T/ac. in Elgin County.[14]

The Huron area is much smaller than the three areas mentioned above, and more emphasis is placed on cropped land. The interest of this area lies in its large acreage of beans.[15] The validity of the consideration in the earlier work by this author, of only hay, small grains, corn and pasture as the crops directly related to the production of livestock may be thoroughly tested in this area. Large acreages of other crops may, or may not, affect the interpretation of farm type by the triangle method proposed in Chapter IV. If the assumption that these other crops are not related to livestock production is valid their presence should make no difference. This area is similar to the Wardsville area in that many farmers keep beef cattle for only the winter months.

3.3 Selection of Sample Farms in the Major Sample Areas

All of the farmers in each area were interviewed. The refusal rate was less than five percent. In that the model against which the sample farms were tested was designed to predict cattle numbers, those

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[14] Ag. Stats., op. cit. p. 52 and 58 respectively.

[15] P. Philpotts, and V. Wallen, op. cit.

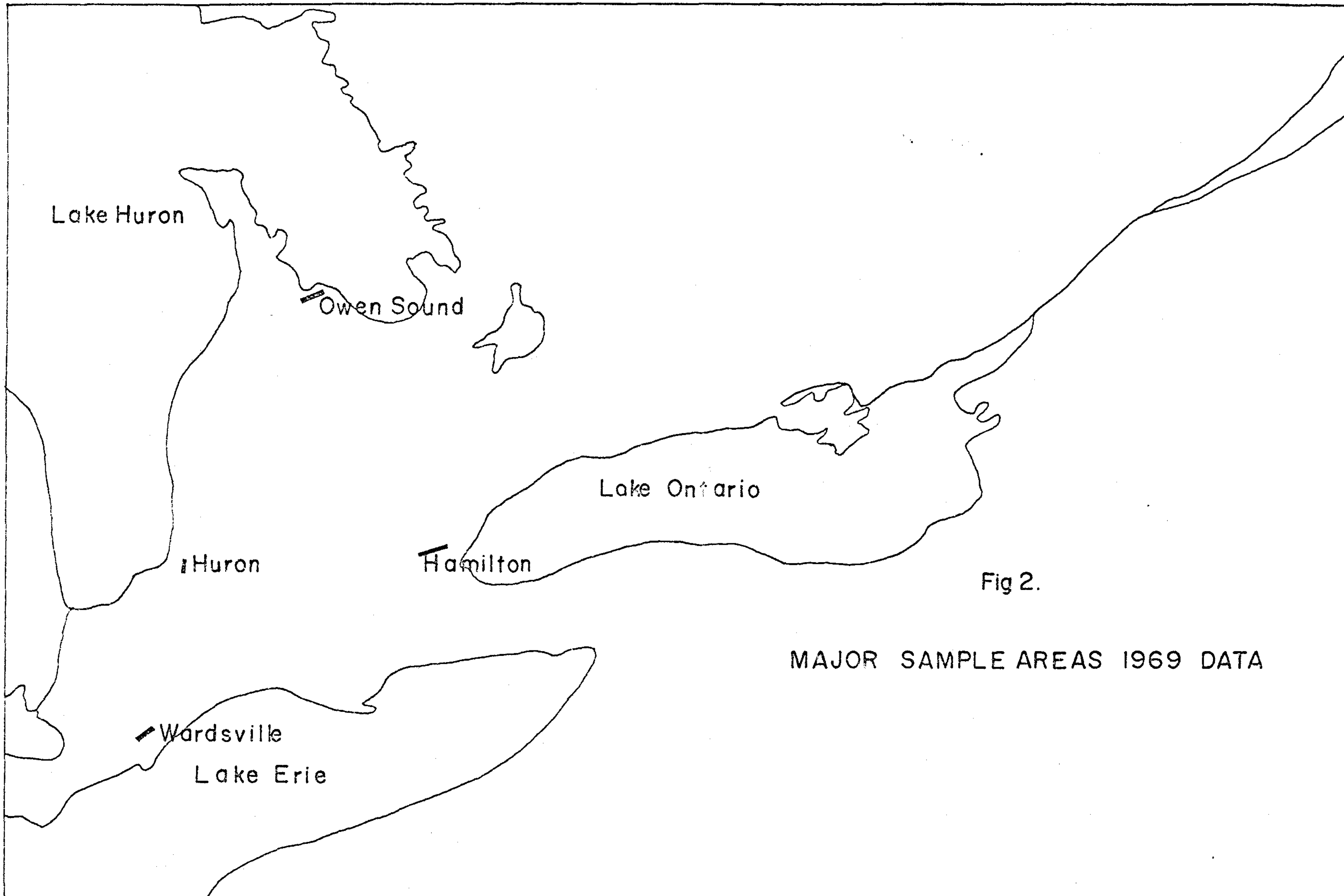

Fig 2.

MAJOR SAMPLE AREAS 1969 DATA

farms without cattle were not considered. Further, farms with a major emphasis on hogs were also ignored.[16] Other farms were removed if more than four or five fields were not on the photo run. If only a few fields were not on the photographs the interviewer would ask their sizes and crops. The area handled in this way had to be kept to a minimum as it was determined on the basis of earlier studies that the farmer's estimation of his acreages is often inaccurate.[17]

Since buildings are also very important to this study, if a farm's buildings were not imaged on the photographs the farm could not be included for full testing.

From the sample of 432 farms in the four study areas a usable set of 81 cattle-raising farms emerged.[18] The operators of each of these 81 farms were then interviewed.

3.4 Interviewing in the Major Sample Area

The on-farm interviews were conducted at the farmer's leisure, often after several call backs. The questionnaire was made flexible in order to elicit maximum information by allowing the farmer freedom to digress. Earlier experience demonstrated the difficulty in obtaining

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[16] If a farmer raised only a few litters of young pigs, his farm was included in the study.

[17] L. E. Philpotts, "Farmer's Estimation of Acreage in Comparison with Measurements from Aerial Photographs", Canadian Farm Economics, June, 1966.

[18] The nature of the operation was determined from earlier interviews in the case of all areas except Huron.

precise information concerning production figures from farmers. It was found, in a pilot study in the Hamilton area, that such a loosely structured questionnaire in conjunction with a sympathetic approach to the farmer's problems by the interviewer resulted in less reticence on the part of the farmer. As a result of this pilot study the earlier questionnaire was discarded, and the interviewing technique was modified to its present form.[19]

The data obtained from these interviews and those obtained from measurement on the aerial photographs are presented in Appendix B.

3.5 Selection of Sample Farms in the Minor Sample Areas

In order to provide a check on the accuracy of some of the assumptions concerning crops and identification of farm types (cattle for either beef or dairy) (to be developed in Chapter IV) a further sample of farms has been used. This sample has been drawn from sixteen widely separated areas in southern Ontario. These sixteen areas include farms from virtually all farming areas in southern Ontario.

3.6 Interviewing in the Minor Sample Areas

In the summer of 1968 a total of 452 on farm interviews were conducted by this author.[20] Costs prohibited photo coverage. All

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[19] See Appendix A for questionnaire and interviewing methods.

[20] The interviews were conducted by this author when an undergraduate research assistant for Dr. H. A. Wood.

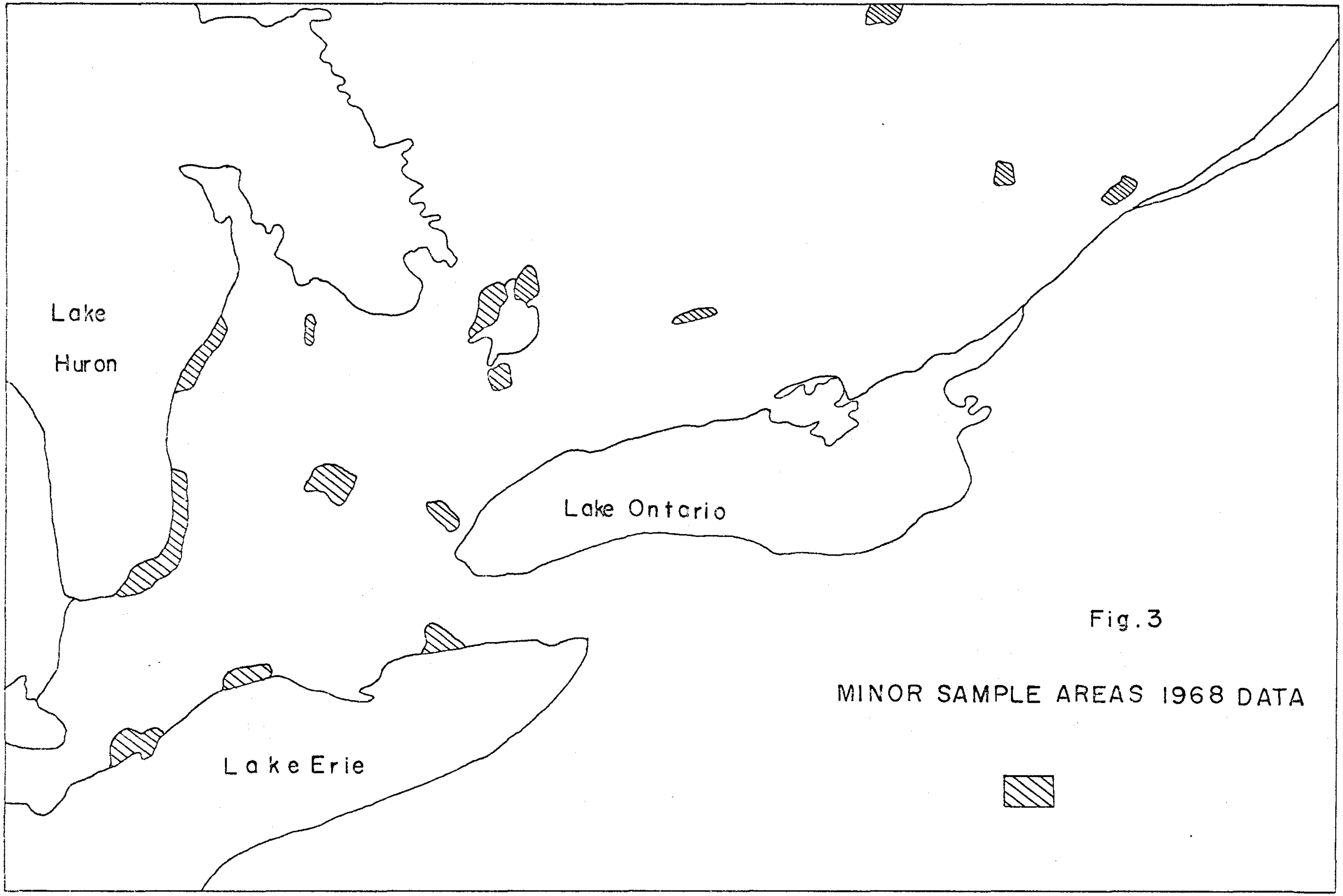
Lake
Huron
Lake Ontario
Lake Erie
MINOR SAMPLE AREAS 1968 DATA

Fig. 3

farms in the study areas were visited. If the farmer was not available, or refused to give time for an interview, no call backs were made. 269 farms included the parameters with which this study deals. Farmers not at home were ignored. The sample does not exhaust the sample space. Further there are no checks on the farmer's accuracy of estimation of acreages. For these reasons, and others not deemed as important, this sample may be said to be less rigorous than the sample drawn from the four major sample areas.

3.7 Summary

With all of the inaccuracies that may exist in this "minor" data it does provide a check on the general applicability of the methodology introduced herein. If the method is indeed flexible enough to be reasonably accurate for widely separated and very different types of farming operating under different environmental constraints and with imperfect data it must have considerable inherent strength.

The sample of 81 farms includes most possible combinations of the major external controls: type of operation, farm crops, and building design. Further, the farm size and carrying capacity vary greatly. These diverse elements are all set in a varying environmental framework. The sample size, (in combination with the varying methods of farming) allows one to draw significant statistical inferences concerning the probability that may be attached to the proper prediction of cattle numbers using the methodology presented in this study. For the aforementioned reasons the sample areas selected would appear to provide an adequate real world situation against which one may test the thesis of this study.

CHAPTER IV

DEVELOPMENT OF THE CROP MODEL

4.1 Farm Type Identification

Before one may begin the development of a model which is based on crops and designed to predict livestock numbers on a given farm, one must know what type of operation is present. Goodman suggested a method for separating dairy and beef farms.[1] However it was found to be inaccurate in the earlier work by this author.

As an initial step it was necessary to discover some theoretical basis for determining farm type from air photo observations. This task was confronted by the author in 1968[2] and a solution found in the feed composition recommendations set out by the Ontario Department of Agriculture.[3] A number of feed mixes of specific weights for each of corn, hay and grain are listed for each broad type of operation. Each recommended feed mix or feeding system can then be expressed in terms of equivalent crop acreages, since one knows the feed weight

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[1] M. S. Goodman, (1964), op. cit.

[2] R. A. Ryerson, op. cit. p. 49.

[3] Dairy Husbandry in Ontario, op. cit. and Beef Husbandry in Ontario, op. cit.

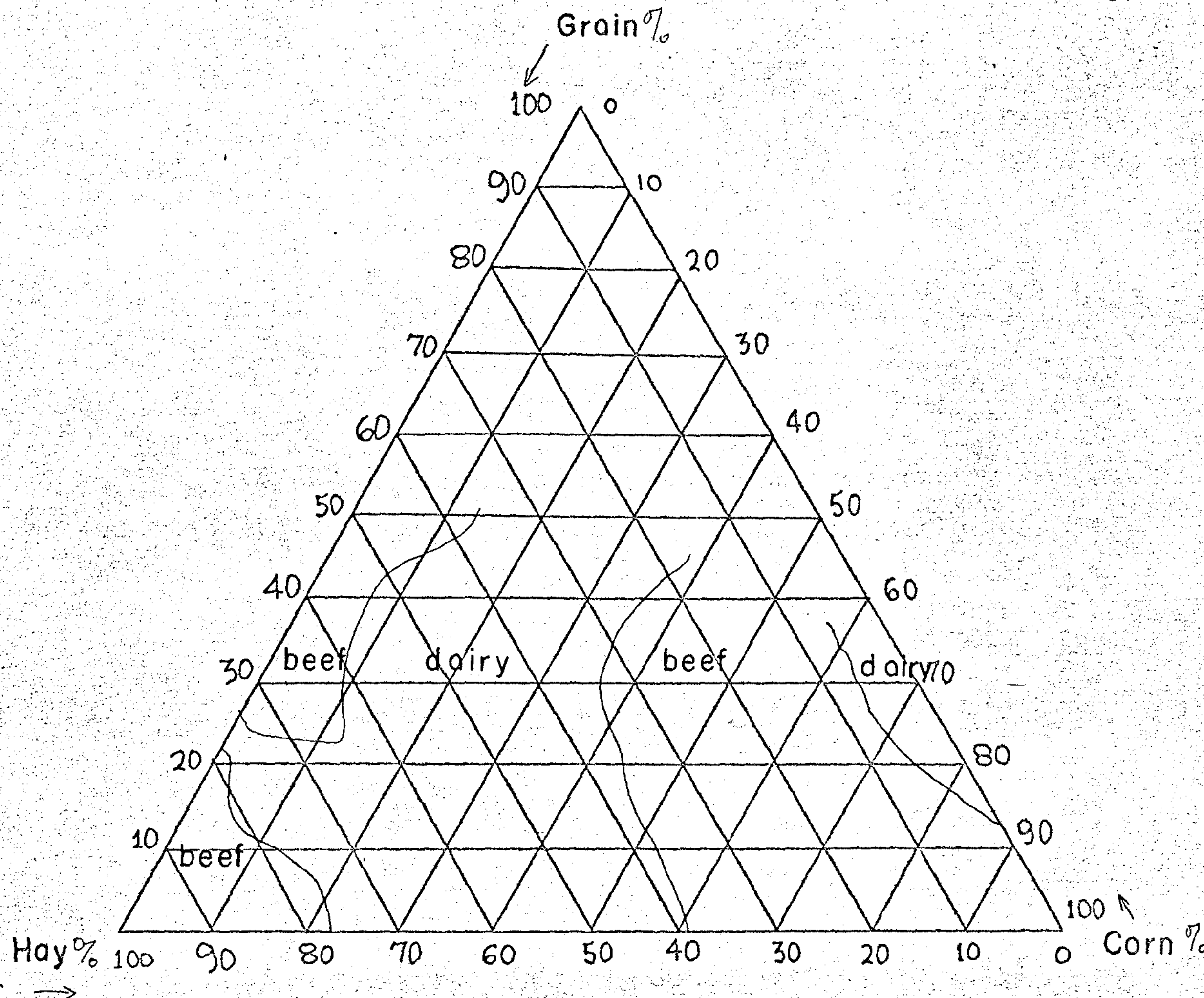

Fig 4

DETERMINATION OF FARM

TYPE

required as well as the crop yields per acre.[4] These feed prescriptions, expressed in acreage ratios, have been found to vary by type of operation when set out on the triangle diagram (Figure 4) described above. One may note the presence of specific areas for each of beef and dairy farming on the triangle. It follows that one may separate actual farms into dairy and beef types on the basis of the location on the triangle which corresponds to their crop ratios.

Given the theoretical crop acreage requirements for dairy and beef farming expressed as ratios as in Figure 4, and given the ability to measure corn, grain, and hay (including pasture) acreages on a given farm, one may determine farm type.

Considering the development of the above deductive construct, it seems logical that one would also be able to differentiate between types of beef farming, since cropland ratios are controlled, to a large degree, by feeding systems and these in turn are controlled by the specific type of operation. It has been decided to apply empirical evidence derived in this study to attempt to provide a more sophisticated method of determining the specific type of beef farming. In this way the triangle (Fig. 4) may be subdivided into types of beef operation. Table 1 provides the age breakdowns used in Figure 4.

From these subdivisions one should be able to develop a probability surface. Then one could state, with given probability,

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[4]From Ag. Stats., op. cit.

the type of operation class in which a given farm falls.[5]

Thus one external variable[6], that of farm type, is determined as the first phase in the establishment of the crop model. The importance of this step will be made more apparent in the following discussion.

4.2 Crop Model Basis

To this point much general detail on land use ratios has been drawn from an earlier study by this author. When specifically considering cropland requirements for each of dairy and beef cattle this exploratory work falls short. All but the most basic assumptions made in that study must be discarded as either naive and/or totally incorrect.

Those assumptions that remain are based on documented evidence, as such they are considered to be facts. The facts are as given below:

1. "cattle require specific foods in specific quantities to maintain a desirable level of production. Any method of cropping must permit the attainment of this standard."

2. "The type of livestock is another significant factor. The carrying capacity of any given farm for dairy cattle may be proved to be significantly different from its carrying capacity for beef cattle. Dairy and beef cattle need different feeds in different combinations in order to satisfy 1. above."[7]

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[5]Building types and farmstead arrangements as keys to the type of operation will be discussed in the next chapter.

[6]As defined in Chapter II.

[7]These assumptions are based on data taken from the Ontario Department of Agriculture's handbooks on Dairy and Beef Husbandry. The statements, as outlined here, were first presented by Ryerson, op. cit. pp. 15 and 16 respectively.

Upon these two statements one may build a method to measure cattle carrying capacity.

4.3 Dairy Cattle Feeding

First, considering dairy cattle, the required amount of roughage or succulent feeds (hay and corn silage respectively) is based on the weight (in cwt.) and age of the cattle in question. In that various cattle breeds are of varying sizes a problem arises. One must assume an average animal size. The only data available for proportions of various breeds in a given cattle population relate to the total cattle population of the province of Ontario. The average cattle weights are derived in Table 2.

The amount of grain fed is based on several criteria. These various criteria raise a complex series of problems. Furthermore, as noted below many farmers grow grains for both feed and cash crop. Other farmers buy some or all of their grain or concentrates. Furthermore yields of one grain crop can vary from the yields of another crop in the same area by as much as 800 pounds per acre.[8]

The weights of grain and concentrates fed are "dependent on the amount and quality of roughage fed."[9] Quality of roughage is in

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[8] Ag. Stats., op. cit., pp. 30 and 42.

[9] Dairy Husbandry, op. cit., p. 42.

TABLE 1

A SAMPLE DETERMINATION OF EACH AGE CLASS*

FOR DAIRY AND BEEF IN WELLINGTON COUNTY

Age and Purpose	No. in County	
Cows for milk (2 years +)	33,900	
Cows for beef (2 years +)	11,500	
Yearlings for milk	9,500	
Yearlings for beef	14,300	
Calves (under 1 year)	31,000	- assume calves are equally divided by percent of total in each of dairy and beef.
Steers (one year +)	45,000	

Separating into dairy cattle and beef cattle:

DAIRY		BEEF	
Calves	31%	Calves	14%
Cows	54%	Cows	14%
Yearlings	14%	Yearlings	17%
		Steers	55%

*Source: Agricultural Statistics for Ontario, Ontario Department of Agriculture Publication 20.

TABLE 2

DAIRY CATTLE WEIGHTS AND AGES*

BREED	AYRSHIRE	GUERNSEY	HOLSTEIN	JERSEY
Calf - weight at 5 mo.	245	216	299	200
Heifer - weight at 12 mo.	538	490	632	450
Cows - weight at 4 yrs.	1035	990	1232	897
% of Ontario's Registered Cattle	04.5	06.0	80.0	09.5

Weighted means of weight in Ontario:	Calves	-	282
	Heifers	-	602
	Cows	-	1174

*Source: Dairy Husbandry in Ontario, derived from data on pages 9 and 99.

TABLE 3

FEEDING RECOMMENDATIONS FOR GRAIN-DAIRY*

CALVES - (p. 56, Dairy Husbandry) 396 lbs. corn, 522 lbs. cereal grain, this covers nine months.

HEIFERS - feed three pounds of grain per day.

COWS - dry for 61 days per year, on 40 of these days grain is not fed, on the other 21 feed at the rate of 10 lbs. per day per cow.

- wet for 305 days. There are various guides for producing cows. Assuming the butterfat content as 3.95% and the weight of milk produced as 38.0 lbs. per day (305 days); the charts given on pp. 46-47 in Dairy Husbandry in Ontario give the following requirements:

CLASS OF ROUGHAGE	WT. OF GRAIN/DAY/COW
A - Excellent pasture	3.5 lbs.
B - (Good, pasture, etc., high green, high protein hay)	7.5 lbs.
C - (Good hay, fair pasture, silage)	11.5 lbs.

*Feeds based on the production for the hypothetical cow arrived at in Table 2.

turn dependent on the amount of "legume in the hay ... (and) ... the (hay's) stage of maturity".[10] Farmers are also directed to "feed concentrates according to the cow's level of production."[11] (Table 3)

In order to deal fully with these variations, complex, and possibly unmanageable, criteria for the feeding of grains would be necessary.

Problems of parameter measurement are present with regard to animal production criteria. Inferences concerning milk yields, or butterfat content, would appear unreliable, for a small percent variation in milk yields or butterfat content could substantially change the required grain mixes.[12] Further, the amount of grain fed is also dependent on whether the cow is put in calf during a given year.

On the scale of imagery selected some grains may not be easily differentiated, (e.g., wheat and barley) therefore, yields by grain type cannot be determined. Similarly the scale and type of imagery is not adequate for interpreting quality of roughage. Time of cutting, which is related to maturity, cannot be determined by a single flight. Therefore two of the criteria for the feeding of grains cannot readily be determined from air photo interpretation.

For the above reasons one must use care in making assumptions

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[10] ibid.

[11] ibid. p. 43.

[12] ibid. p. 42.

concerning the feeding of grain. The limitation on accuracy discussed above serves to remove acreage of grain present on a given farm as an important feature in the measurement of feeds available on a given farm.

The required weights of roughage or succulent feeds for dairy cattle are clearly set out,[13] and are not affected by variation in the quality of roughage. The acre of pasture has been considered to represent 0.6 acres of hay.[14]

The identification of corn is easy, but the distinction between cob corn and corn used for silage proves to be a very important problem. The current scheme relies on the measurement of silo capacity, which is feasible with the given scale and stereo coverage. Several charts are available to convert the silos volume capacity to the weight of feed it can contain.[15]

If the farmer uses bunker silos these too may be measured for capacity. The only problem one may encounter is the use of storage on the ground covered (sealed) by plastic. One may assume methods of measuring these piles could be developed.[16] No such procedures have

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[13]These roughage mixes are outlined in Table 4 on the following page.

[14]J. D. Curtis, op. cit.

[15]The Chart of Soil Capacity in Dairy Husbandry in Ontario, p. 97, is reproduced in Table 5.

[16]Such a method would simply require a detailed study of the methods suggested for piling silage in this fashion.

TABLE 4

ROUGHAGE MIXES FOR DAIRY*

	HAY	HAYLAGE	CORN SILAGE
r1 (roughage mix 1)	2		
r2	1.5		3
r3	1.5	2	
r4		2	3
r5			6

*Based on pounds fed per cwt. liveweight of cows. Taken from Dairy Husbandry in Ontario pp. 38-39.

TABLE 5

SILO CAPACITY IN TONS*

SILO WIDTH	14	16	18	20	24	30
SILO HEIGHT						
20	54	70	89	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	284	350	503	788
50	200	261	330	407	583	913
55	230	301	380	468	673	1060
60	260	341	430	529	760	1190

*Suitable for all ensilage crops except hay. SOURCE: <u>Dairy Husbandry in Ontario</u>, <u>op. cit.</u> p. 97.

been encountered in the 350 farms interviewed and accepted as cattle farms.

The weight of silage derived from the silo measurements is accepted as the silage weight fed if this value equals, or is less than, the weight of the corn weight available on a given farm.

This may be stated more simply:

$$\frac{W_{sj}}{Y_i} \leq A_{cj} \qquad \text{and } W_{sj} = F_{cj}$$

$$\text{if } \frac{W_{sj}}{Y_i} \geq A_{cj} \quad \text{assume amount fed } F_{cj} = A_{cj} \times Y_i$$

where: W_{sj} is the silage capacity expressed in pounds on the jth farm.

Y_i is the average yield of fodder corn per acre in the ith county.

A_{cj} is the acreage of corn on the jth farm.

F_{cj} is the fodder corn fed on the jth farm.

It follows that: $\frac{W_{sj}}{Y_i}$ = acreage of corn silage stored in the given structures

The production of hay on a given farm is more easily determined since it may be assumed that all hay is used as feed.

Hay fed on the jth farm is given by:

$$F_{hj} = A_{hj} \times Y_{hi}$$

where: A_{hi} is the acreage of hay on a given farm

Y_{hi} is the average yield of hay in the ith county.

One may now determine how many cattle this feed can support. First one must consider the earlier mentioned fact: cattle of different types and ages require different weights of feed. The suggested age ratios of cattle used for dairy purposes are eight or nine young (four heifers and four or five calves) for every ten cows)[17].

Table 6 outlines the Daily Dairy Feed Requirements for the hypothetical average dairy animals arrived at in Table 2. Table 7 outlines the same feed requirements for a six month period.[18] These figures are translated into acreages by dividing them by the average yields in the area under consideration. For example, in a six month period using roughage mix #1 (from Table 6) a dairy cow in Wentworth County (which has a hay yield of 5920 pounds per acre)[18] requires .66 acres of hay.

By dividing acreage present on any given farm by the feed required per set of animals (e.g. .8 young for every cow), one may

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[17] Dairy Husbandry in Ontario, op. cit. pp. 16-17.

[18] The importance of using the six month interval will be brought out in the discussion of the feeding of beef cattle. Further one should note the importance of pasture. If adequate pasture is present the cattle will be kept on the pasture (for it is generally considered better feed) for the warm months.

TABLE 6

DAILY ROUGHAGE REQUIREMENTS* FOR DAIRY (in pounds)

FOR COWS

	HAY	HAYLAGE	CORN SILAGE
r1	22		
r2	16		34
r3	16	22	
r4		22	34
r5			68

FOR HEIFERS

	HAY	HAYLAGE	CORN SILAGE
r1	12		
r2	9		18
r3	9	12	
r4		12	18
r5			36

*From Dairy Husbandry in Ontario and combination of Tables 2 and 4, pages 34 and 37 respectively, of this study.

TABLE 7

ROUGHAGE FEED REQUIRED BY DAIRY CATTLE

OVER A SIX MONTH PERIOD* (in pounds)

FOR COWS

	HAY	HAYLAGE	CORN SILAGE
r1	3960		
r2	2880		6120
r3	2880	3960	
r4		3960	6120
r5			12240

FOR HEIFERS

	HAY	HAYLAGE	CORN SILAGE
r1	2160		
r2	1620		3240
r3	1620	2160	
r4		2160	3240
r5			6480

NOTE: If there is no pasture these figures must be doubled to obtain the required weights of feed for a period of one year. If one acre of pasture is present for each set of cow and calf assume adequate pasture to feed for the summer. Every set of cow and young not so supplied is assumed fed year-round for stored feed i.e. double the above figures.

*This table has been arrived at by considering a six month interval. Each month is considered to have 30 days. Therefore, this chart is directly derived from Table 6.

TABLE 8

ROUGHAGE FEED REQUIRED BY DAIRY CATTLE SETS

OVER A SIX MONTH PERIOD (in pounds)

per set (1 cow +0.8 young)

	HAY	HAYLAGE	CORN SILAGE
r1	5688		
r2	4176		8712
r3	4176	5688	
r4		5688	8712
r5			17424

The above is derived from Table 7, combined with the assumption that the cow/heifer ratio is 10/8.

TABLE 9

TYPES OF BEEF OPERATIONS (AGES AND WEIGHTS)*

AGE	WEIGHT
Calves	400 lbs.
Yearlings	675 lbs.
2 years (young cows)	925 lbs.
mature (cows)	1100+ lbs.

STEER - yearlings fed up to marketable weight, all animals the same age.

COW-CALF - raise cows as well as the calves from each cow. Assume only cows and an equal number of calves.

STOCKER - feed steers over the winter, usually done by cash crop farmers as a sideline in the less busy period of the year, i.e., from October to early spring, a period of approximately six months.

*Information taken from Beef Husbandry in Ontario, op. cit.

arrive at an estimation of the number of cattle the feed grown on the farm can support. The feed for one set is given in Table 8.

4.4 Beef Cattle Feeding

When dealing with the feed requirements for beef cattle many of the same problems are encountered. Breed is not markedly important. Type of operation and the use to which the animal is put are the key influencing factors.

The crop triangle presented on page 34, in conjunction with the barn layout, gives the key to the specific type of operation under the generic name beef farming. These operations may be defined as stockers, cow calf, and steer feeding.[19] The latter is often carried out in feedlots, and the farms on which the cattle are fed do not grow the feed being fed. Therefore the building key must suffice as an estimate of the number of cattle.

As is the case with dairy feed requirements, only hay, pasture, and corn silage[20] are considered integral to the feeding of beef cattle. The required weights of these feeds are clearly set out for each type of operation, and, like dairy feeds, are independent of quality of roughage.

The methods of determining the amounts of hay and corn silage

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[19]See Glossary of Terminology.

[20]<u>Beef Husbandry</u>, <u>op. cit.</u>, pp. 20-21.

available are identical to those presented for dairy cattle on page 42. Unlike the dairy feeding, however, there are several types of operation, each requiring a different feed system.

The nature of these operations dictates consideration of cash crop farmers who feed cattle only during the winter. To determine the number of cattle on these farms, it may be assumed that the feeding period is six months in duration. For this reason great error is avoided if one notes the existence[21] of this type of operation. It is clear that if such a farm is assumed to keep cattle all year the turn-over measured is only one half of the actual output of cattle.

Consistant with the development of the dairy cattle feed requirements is the tabular outline of type of operation, weight and size of animal, and feed required per animal.

By dividing required feed per animal into feed available for a given operation one may obtain the number of animals that could be fed on a given farm.

4.5 Summary

A methodology to determine the number of cattle that could be fed with the feed available has been presented. The concepts behind the methodology presented above are admittedly simplistic. One must note, however, the number of variables that have been built into the

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[21]Generally no pasture, some hay, and usuable animal barns and silo. Large grain or corn acreage.

TABLE 10

DAILY ROUGHAGE REQUIREMENTS FOR BEEF (in pounds)*

FOR MATURE CATTLE

	HAY**	CORN SILAGE
r1	21	
r2	10	33
r3		55

WINTERING YEARLING HEIFERS AND STOCKERS

	HAY	CORN SILAGE
r1	20	
r2	3	45

*From Beef Husbandry in Ontario, op. cit. The weights are an average of the suggested weights which cover a wide range. For example r1 for mature cattle may be 16 to 25 pounds. Size of animal and breed are secondary. Stated more clearly, the animal's size is assumed to be at a given level for the age or uses stated.

**Hay may be replaced by the words legume or grass hay. If grass hay is fed, more grain, or concentrate is required.

TABLE 11

ROUGHAGE FEED REQUIRED BY BEEF CATTLE

OVER A SIX MONTH PERIOD* (in pounds)

FOR MATURE CATTLE

	HAY	CORN SILAGE
r1	3780	
r2	1800	5490
r3		9900

WINTERING YEARLING HEIFERS AND STOCKERS

	HAY	CORN SILAGE
r1	3600	
r2	540	8100

NOTE: If there is no pasture these figures must be doubled to obtain the required weight of feed for a period of one year

*This table has been arrived at by considering a six month interval. Each month is considered to have 30 days. Therefore, the table is directly derived from Table 9.

method. With one notable exception, virtually all of the factors discussed in the preceding chapters have been included.

The exception referred to above relates to the housing of the animals. This is dealt with in detail in the next chapter, "Development of the Building Model".

CHAPTER V

DEVELOPMENT OF THE BUILDING MODEL

5.1 Introduction

Earlier in this study it was stated that "cattle require adequate shelter". Further, the assumption was made that livestock carrying capacity is related to the building size and design. The justification of this assumption is now in order.

"The first need of housing structures for beef cattle is to give protection to the animals during severe and stormy weather, and to the cows at calving time during winter months."[1]

For dairy cattle "an efficient and well designed building layout should not only provide adequate housing ... but (also) ... should ensure a sanitary and comfortable environment for the dairy herd".[2]

Generally then, for both beef and dairy herds, the barn structures must serve as shelter against the elements. Assuming the farmer seeks to maintain production and herd health, it is also assumed that he will follow the minimum space requirements set out by the Ontario Department of Agriculture.

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[1] Beef Husbandry in Ontario, op. cit., p. 44.

[2] Dairy Husbandry in Ontario, op. cit., p. 78.

5.2 Dairy Buildings

In the above quote concerning the housing of dairy cattle it was noted that the farmer should strive to provide a "sanitary and comfortable environment for the dairy herd". One should avoid crowding. Following from this are the space requirements set out by the Ontario Department of Agriculture. These place specific limits on the number of cattle that can be housed in a given structure of given functional design.

From these guidelines, introduced below , one may determine a barn's maximum capacity. For example, a two storey conventional barn one hundred feet long, and thirty-eight feet wide, should be used to house no more than thirty to thirty-two milking cows, with a total herd size of approximately fifty-five. Even if this farmer produces enough feed for seventy-five cattle, including forty cows, it is unlikely he would have that many, for the barn space would be prohibitively small. In this way the barns can provide a limitation on livestock carrying capacity in dairy farms.

In general the same is true on beef farms, though beef cattle may be housed in many different ways and the animals may vary greatly in size, age, and purpose. Thus, the analysis of beef housing requires knowledge of type of operation and detailed interpretation of barn structures.

5.3 Dairy Cattle Space Requirements

One first may consider stall requirements. There are generally two types of stalls, those in which the animals are tied, and secondly those in which the animals are not tied. Milking in the stall itself is associated with the "tie stall" or "head rail" stall.[3] For dairy cattle the stall width recommended for the largest cow (1600 pounds) is four feet, eight inches. Assuming that the walls of the stall are four inches thick, the stall may then be said to occupy five feet of the barn's length.[4] In order to have two rows of stalls (as had the exampled cited earlier) the barn must be at least thirty-six to forty feet wide (for a tie stall operation without a milking parlour)[5]. If under thirty five feet wide one may assume there are stalls along but one side of the barn, with ancillary pens, etc., facing the one row.

In all of the plans for dairy buildings referred to below seventy-two to seventy five percent of the length of the barn is devoted to stalls (where no other buildings are used to house livestock). Sample designs for loose housing, pole type, single floor and two storey stall barns are outlined in Figure 5.

Dairy barns may generally be identified by the presence of a

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[3] See Glossary.

[4] Dairy Husbandry in Ontario, op. cit., p. 85, For this study the figure of five feet has been arbitrarily selected. Using the smallest stall width given one could conceivably have a stall four feet wide. This, however, would not be suitable for the theoretical "average" sized animal derived in Table 2.

[5] Dairy Cattle Housing and Equipment, Canadian Farm Building Plan Service, Queen's Printer, Ottawa, Ontario, 1966, pp. 5-9.

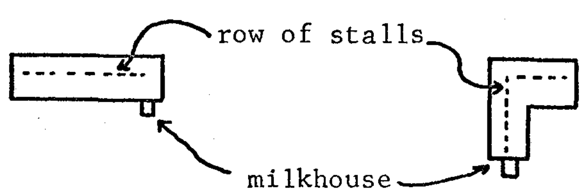
milkhouse (see Figure 5). In some cases dairy barns have no milkhouse or milking parlour. Some produce industrial milk and do not require the bulk cooling and storage facilities afforded by the milhouse, while others have the cooling facilities concealed from view within the basement of the barn.

Loose housing of dairy cattle requires a holding area for milking, and a milking parlour (see Figure 5). Two rows of stalls can be accommodated in barns of this type which are twenty-five feet wide[6]. Stalls are of the same width, and they occupy the same percent of the length of the barn as in the tie stall or staunchion barns.

A second form of loose housing, the pole barn, is also used to house dairy cattle. Three quarters of the area of the barn is used for cows. Each cow occupies fifty-five square feet.

When one has decided that the operation is a dairy farm, application of the following criteria will yield the building capacity.

> If under 35 ft. wide estimate one row of stalls run length of the barn, and assume pens (to house young) etc., run along the opposite wall with an aisle in the middle. This arrangement holds <u>unless</u> the barn is under 30 ft. wide, then assume stalls run 3/4 of the length of the barn.[7] This rule is suitable for barns shaped:



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[6] <u>Dairy Husbandry in Ontario</u>, <u>op. cit.</u>, p. 85.

[7] 3/4 has been substituted for the 72-75% figures given above.

If there is uncertainty as to the way the stalls run, assume:

1. they run away from the milkhouse

2. they usually occupy any new addition to the barn. Any such addition is usually thirty-eight feet wide, and is lower in height than the standard two storey conventional barn.

5.4 Dairy Building Model

Each cow requires a stall five feet wide. The number of cattle is given by dividing the $\frac{(\text{length} \times .75)}{5}$ x # rows of stalls, if only one row, and 30' wide use $\frac{\text{length}}{5}$.

1. If 38'+ wide assume 2 rows of stalls and assume stalls run 3/4 of the length of the barn. The rest is for maternity pens, calves, etc.

2. Free stall, require approximately the same space, but can have two rows in 25 feet, <u>but</u> need a milking parlour, and are generally only one storey. The milking parlour is easily identified (see Figure 5).

3. Pole type barn - estimates 3/4 of area is used for cows, each cow requires 55 square feet.

5.5 Beef Buildings

As mentioned above, beef housing is closely related to type of operation. If a large stockyard is present,[8] for example, one may assume the operation is concerned with the feeding of steers. Pole type barns usually point to the same conclusion.[9] Other criteria for the

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[8] See Figure 6.

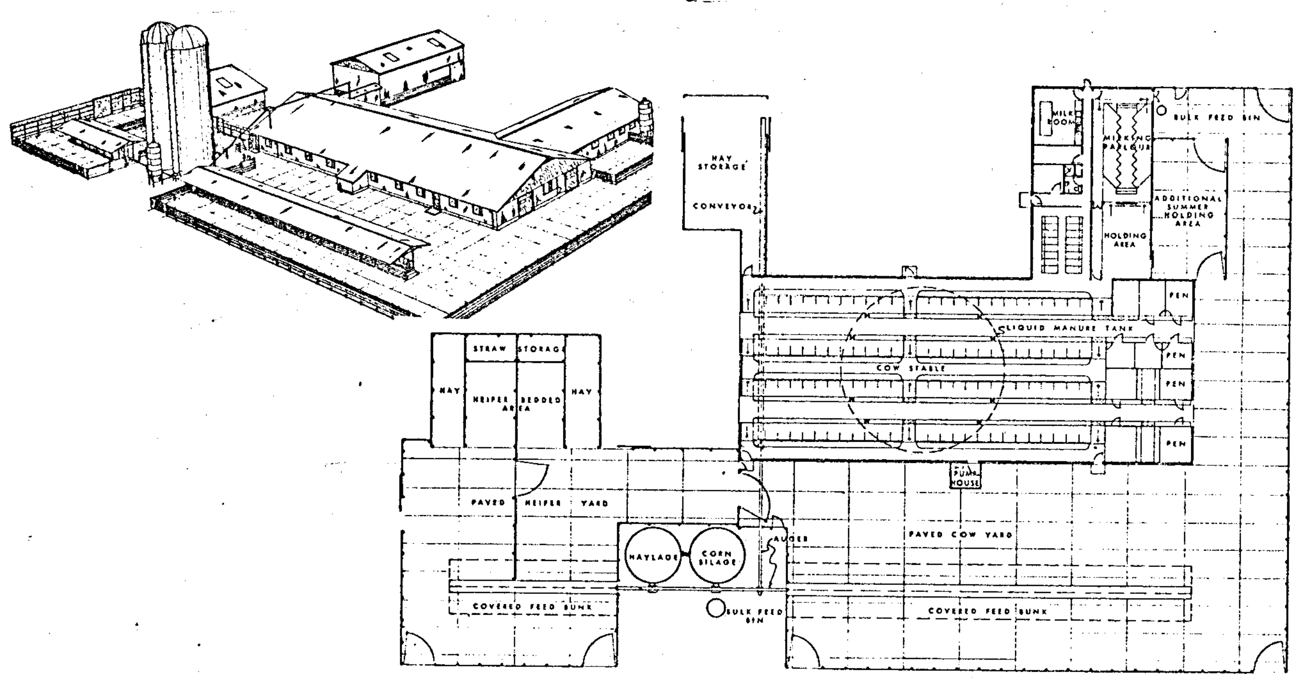
[9] This has been assumed throughout the study, and generally holds true.

Fig. 5
DAIRY HOUSING
(IDEAL HOUSING)

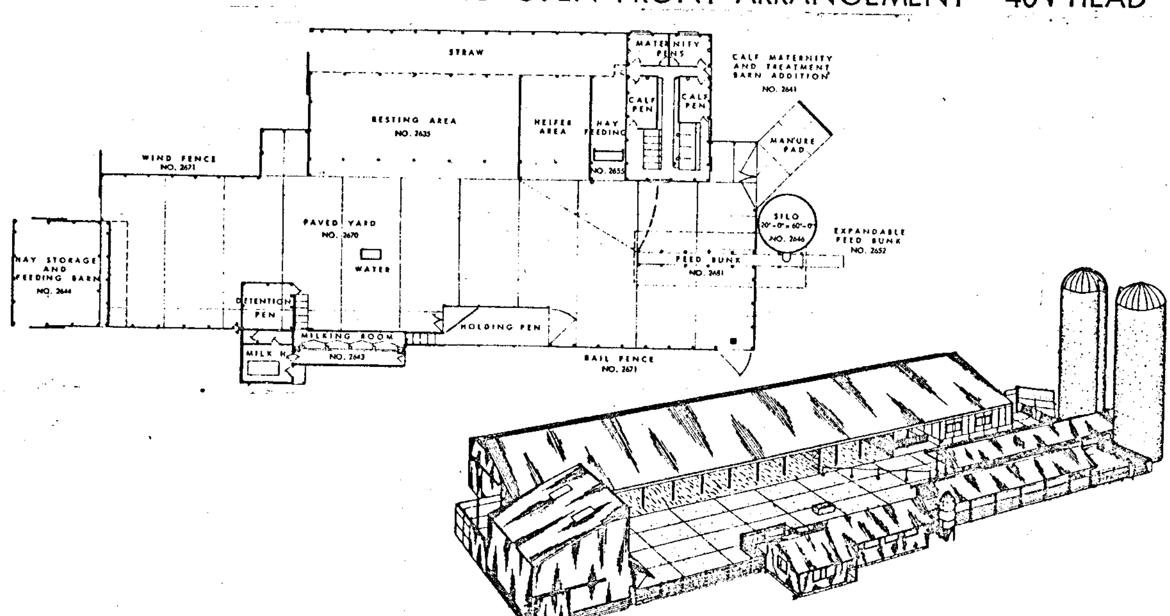
SINGLE-STOREY DAIRY BARN (104 HEAD)

This is a building for a large dairy herd and will accommodate an expansion program. The structure is 66' wide and 177' long and has an extension that includes a milking parlour, milk room and holding area. The main barn has four rows of stalls with raised feed alleys and wide service alleys. The combination stall barn and milking parlour system provides for efficient milking in the summer because the cows do not enter the main barn during this season.

A floor plan shows construction for liquid manure disposal and also described are detailed areas for outside feeding, exercise yards, hay and straw storage.



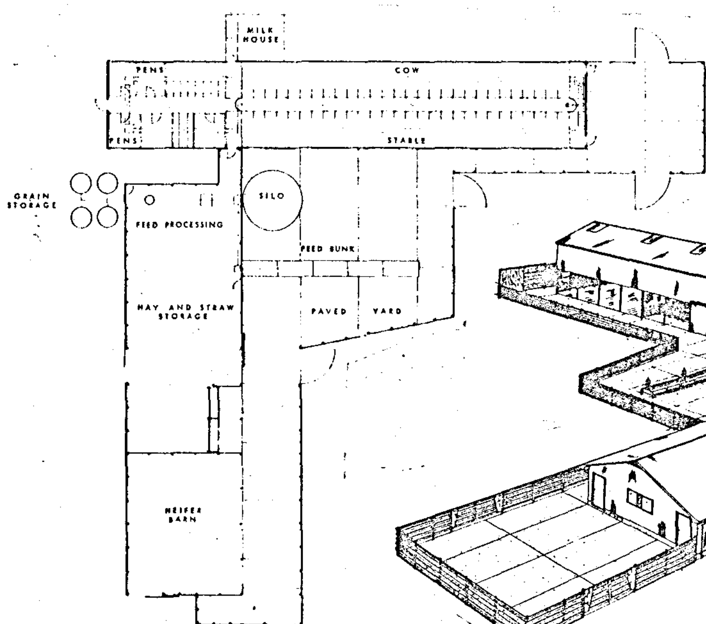
LOOSE HOUSING OPEN FRONT ARRANGEMENT 40 HEAD

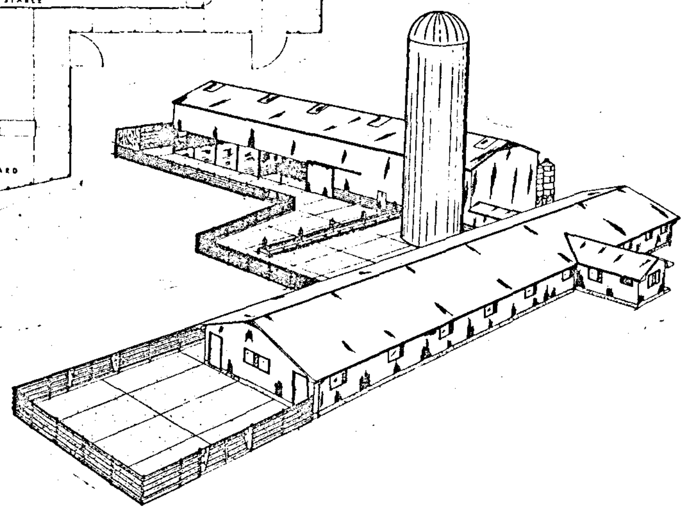


SINGLE-STOREY DAIRY BARN (56 HEAD)

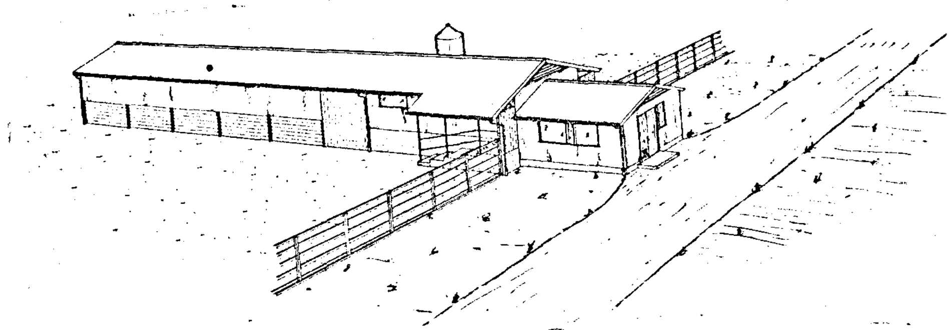
This plan fits a "systems farming" program, ..iat is, a series of buildings each serving a specific function in the over-all plan.

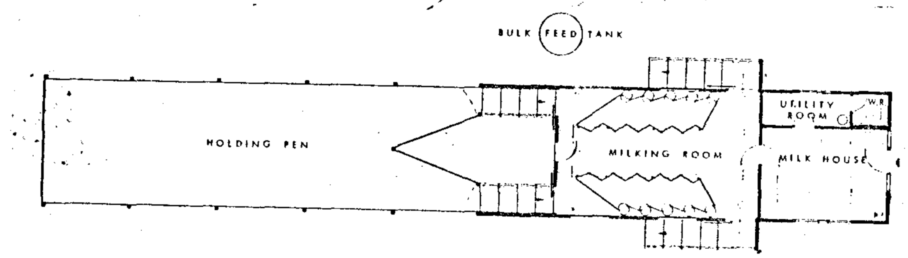
This building houses 56 dairy cattle and is 39' - 8" wide and 140' long. It has areas for heifers, feeding area, hay and straw storage as well as a feed processing unit at one end of the barn.





DOUBLE HERRINGBONE MILKING ROOM

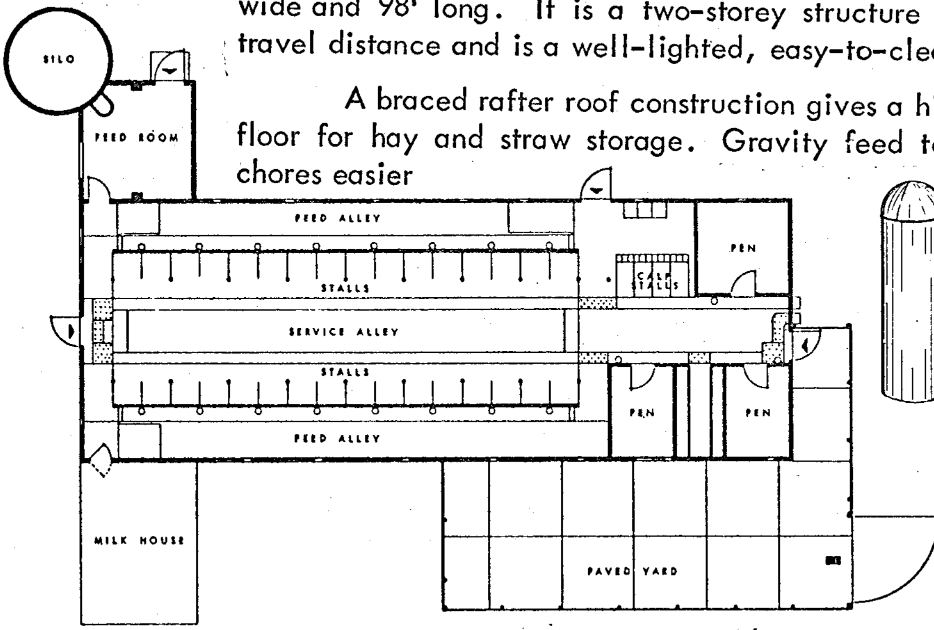


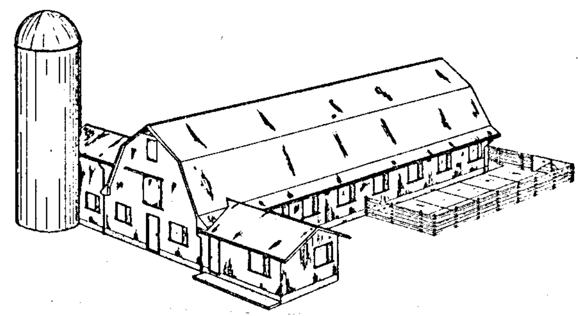


DAIRY BARN (32 HEAD)

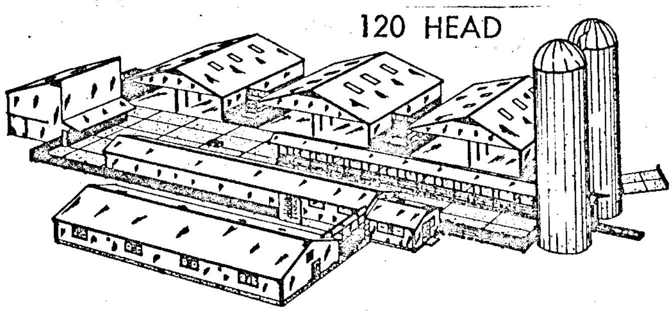
A modern, mechanized building to accommodate 32 head of cattle with provision for expansion if necessary. The building is 36' wide and 98' long. It is a two-storey structure providing minimum travel distance and is a well-lighted, easy-to-clean barn.

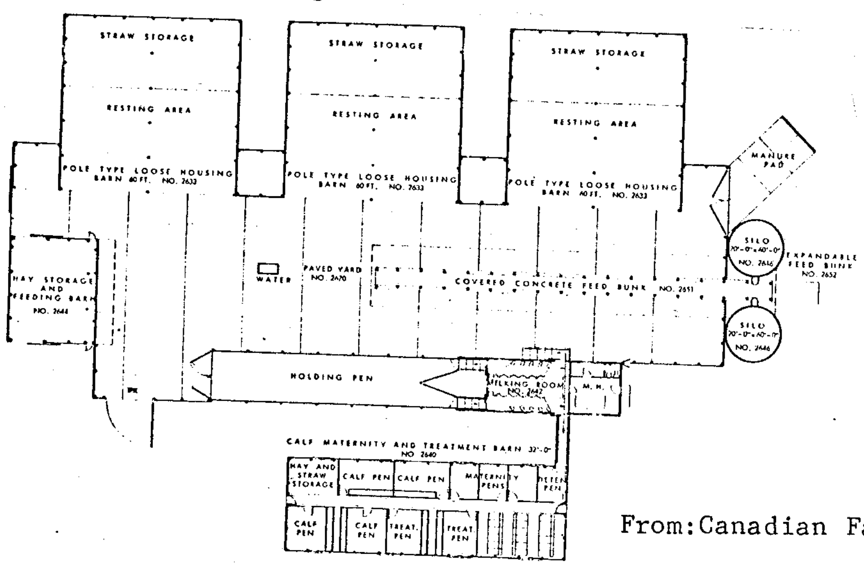
A braced rafter roof construction gives a high post-free upper floor for hay and straw storage. Gravity feed to the stable makes chores easier





LOOSE HOUSING OPEN END ARRANGEMENT 120 HEAD





From: Canadian Farm Building Service

identification of beef farm type are empirically derived in Chapter VI.

5.6 Beef Cattle Space Requirements

Regardless of type of operation the stall width recommended for all cattle (except calves) is four feet. A similar seventy five percent "effective length"[10] of the barn for occupance by stalls holds true. In a beef operation supporting cows one may assume a cow calf operation with one calf for each cow.

5.7 Beef Building Model

The procedure by which one arrives at the parameters for estimating cattle numbers is similar to the method outlined for dairy cattle.

1. Two storey conventional barns, stalls four feet wide and run 3/4 of the length of the barn, two rows in 34 to 38 feet. Where a feed lot is present assume loose housing is used.

2. Loose housing, the cattle occupy 3/4 of the length of the barn, steers require 25 sq. ft. each, cows require 30 sq. ft. each. This housing method is often[11] associated with conventional type barns with a pole type shelter built on to the side of the barn facing on the stockyard.

3. Pole type barn associated with an adjacent stockyard (unpaved) or pasture.

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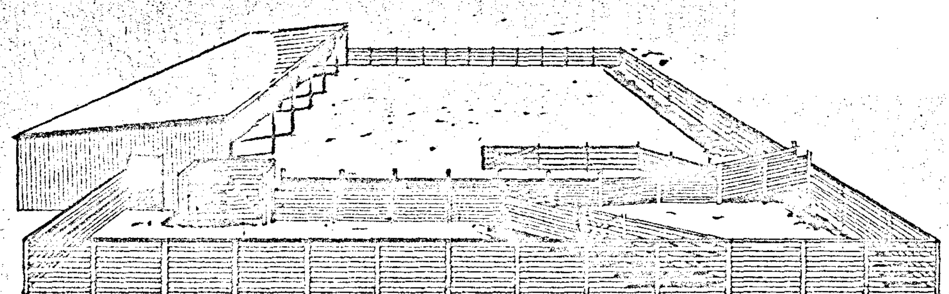
[10] "effective length" is the author's own terminology.

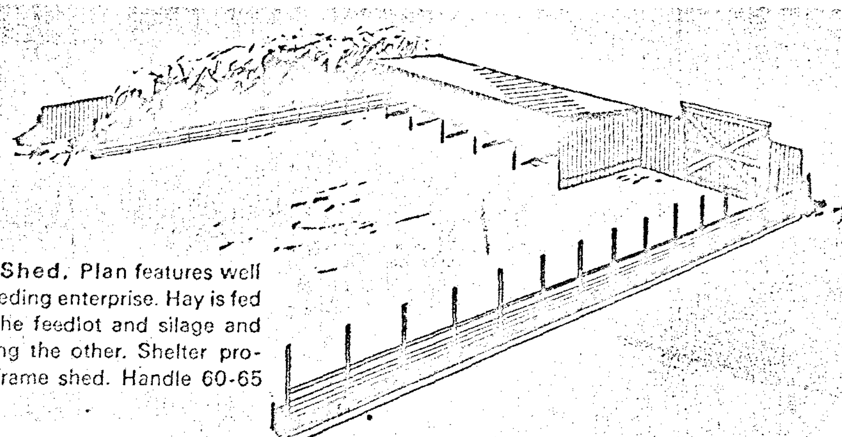
[11] In this study this is assumed to be true in all cases.

Fig. 6

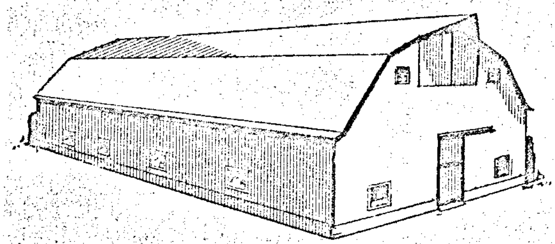
BEEF HOUSING



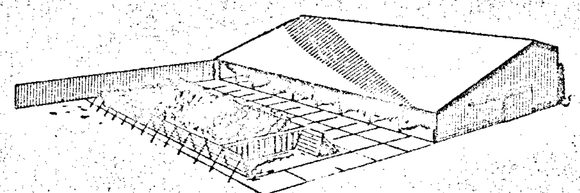
Corral. Corrals provide facilities for branding, unloading, inspection, etc.



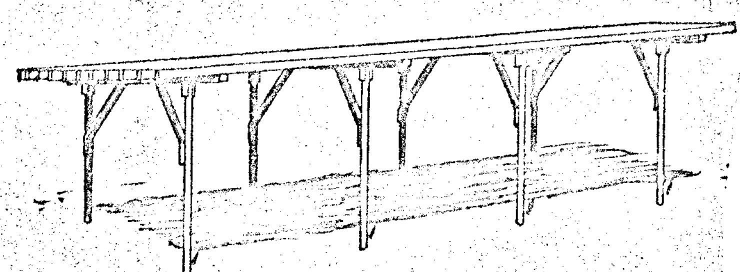
Feedlot and Shed. Plan features well planned steer feeding enterprise. Hay is fed on one side of the feedlot and silage and concentrate along the other. Shelter provided by pole-frame shed. Handle 60-65 feeder calves.



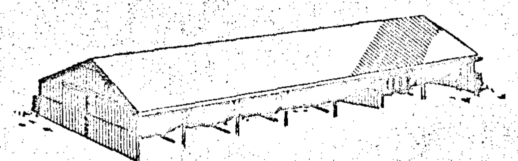
Two-Storey Barn — Overhead Storage. 36′ wide — long as required. Plans include tie-up and loose arrangements, high and low foundations. Mow stores 2 tons of hay per foot of length.



Pole Barn — Open Front. 56′ wide — long as required. Each 14 foot bent houses 8 cows. Large doors each end. Adaptable to any type of beef production.

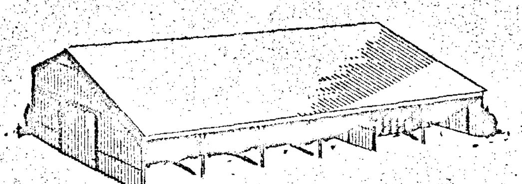


Sun shade. For swine, beef or dairy cattle. Provides shelter in hot weather and protects from rain. Can be placed in exercise yard or pasture.

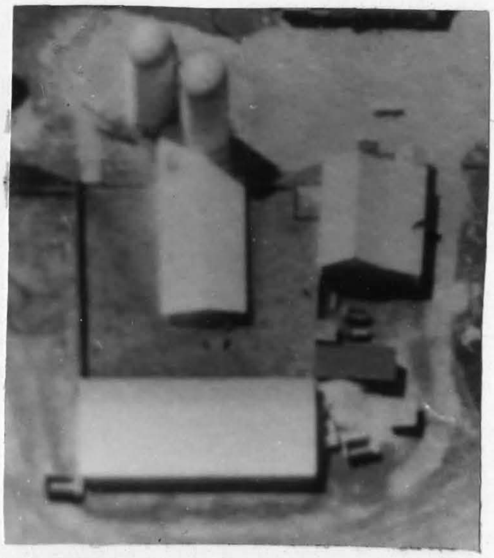


Pole Type Loose Housing Barn Type No. 1. 39' wide — long as required. Consists of resting area, straw and hay storage. Building is divided into 12 foot bents.

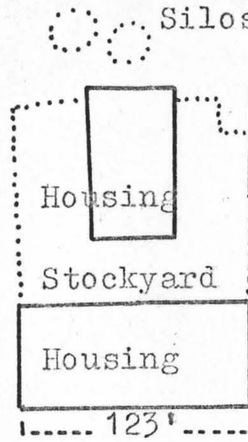
Pole Type Loose Housing Barn Type No. 2. 33' x 84'. Simple design incorporating all the features of loose housing. Easily constructed without experienced labour.



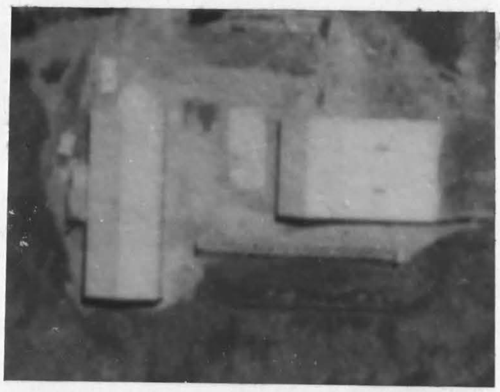
Pole Type Loose Housing Barn Type No. 3. 46'x84'. Expandable to increase herd sizes. Features self-feeding end area. Easy to erect.



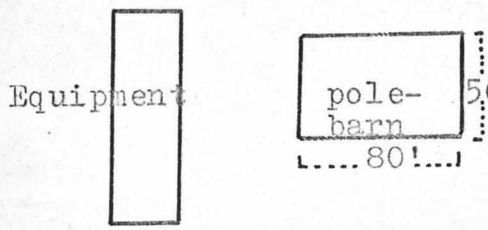
Wentworth # 55



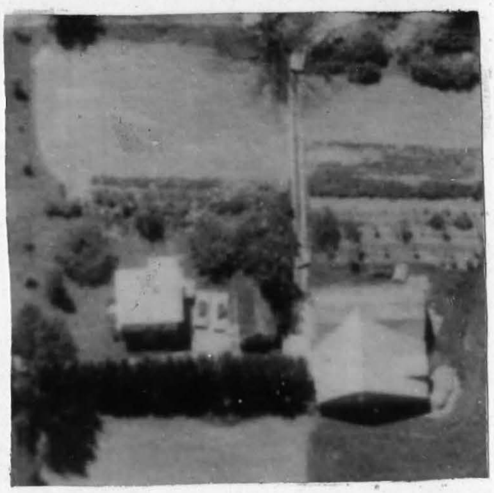
$\frac{10200 \text{ sq.ft}}{25} =$ 408 steers



Wentworth # 118



$\frac{4000 \text{sq.ft.}}{98}$ = 41 steers



Wentworth # 95

conventional barn, 2 rows of stalls in 38 feet, effective length 60', 4' stalls = 30 animals.

Each animal requires 98 sq. ft. (steers and young cows) of the total barn area.

5.8 Interpretation of Barn Uses

A number of keys to type of operation have been empirically derived from earlier field work, and experience in the interpretation of aerial photographs. Generally pole type structures are associated with the feeding of steers. Where associated with the raising of dairy cattle the barns invariably have a milkhouse attached. The milkhouse, a bulk storage area, may also be identified by its location facing on a road or laneway easily accessible to large bulk milk trucks.

The actual distribution of buildings may provide problems for an inexperienced interpreter. A few simple guidelines, as listed below may aid in the identification of a building as one which is used to shelter livestock.

5.7 Summary

The above diagrams provide a means of identifying farm buildings as to their use. Further, a means of estimating their capacity has been presented. The technique, although relatively simple, is believed, by this author, to offer an accurate method of measuring the livestock capacity of barns for virtually all types of cattle raising operations utilizing almost any combination of barn structures found in southern Ontario.

Thus the influence upon livestock carrying capacity of the two major external variables: cropping systems and building capacity, can now be measured and given absolute values. It remains for the following chapter to combine the two into a workable form.

CHART 2

KEYS TO THE IDENTIFICATION OF CATTLE HOUSING

Used for cattle if:

1. one of the largest buildings on the farm;
2. silo(s) adjacent;
3. faces directly on pasture or feedlot;
4. usually downwind or a distance from house.

Generally not used for cattle if:

1. long and low with a steel grain bin at the end; such a structure is usually used for hogs or chickens;
2. long and low and facing directly on a roadway for the greatest part of its length, with no livestock yard at front, one may assume this building is for equipment;
3. unattached and less than 17 feet wide and 30 feet long assume not used for commercial cattle operations.

One should note that many more keys may be derived simply by performing a detailed study of some of the features that are evident in the preceding diagrams of buildings in Figure 5 and Figure 6.

CHAPTER VI

APPLICATION OF THE MODEL AND ANALYSIS OF RESULTS

6.1 Introduction

The application of the techniques presented in the previous chapters is a four stage problem. First one must identify farm type. Second one must measure feed available and crop carrying capacity. Third a measure of building capacity is required. The last stage serves to combine the first three into a composite model that measures the actual carrying capacity of cattle on a given farm.

It has been shown above that the outputs of stages two and three are inter-related. Acreage of crop can be determined for the analysis of crop methodology presented in Chapter IV of this study. These acreages first must be converted to include only those crops that could be used as feed, or as component parts of feed mixes.

Although inter-related, stages two and three may yield answers significantly different from each other. It is the role of the fourth stage, to be developed in this chapter, to inter-relate the three previous steps in light of assumptions based on animal husbandry.[1]

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[1]The reader is reminded of the example mentioned on page 55 A dairy farm may grow the crops to support 75 cattle, but may have space to have only 40 in the farm's barns. Therefore the lowest value would intuitively appear correct, for the cattle require adequate housing in order to survive the rigours of winter.

6.2 Farm Type Identification

The inherent faults in the triangle system of farm type identification proposed and applied below are several in number. The acreage figures are derived from the complicated grain mixes in combination with hay and silage mixes discussed on page 41 of this study. Therefore problems associated with the consideration of grain as a part of feeds for cattle (from page 41 of this study) are present in this method. Secondly, the yield values used are drawn from Wellington County. The broad assumption has been made that yield values for each crop will vary to the same degree from area to area. Therefore the locations of various mixes will remain fixed on the triangle regardless of the test area. This is not necessarily the case.[2] Further it has been assumed that a first order nearest neighbour analysis based on linear distance on the triangle diagram is a viable method of determining to which group a farm belongs. This may, or may not, be a valid assumption.

The farms used for the present study were taken both from the minor study areas, relying on the farmer's estimation of his acreages, and the major sample areas covered by the available photography.[3]

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[2] One need only calculate the percent increase or decrease of hay and grain yields relative to one another from county to county.

[3] The discrepancy between the major sample size (100) for the testing of the triangle method, and the sample size of 81 other parts of the analysis relates to the farms which were omitted in the later analysis for one or more of the following reasons: 1) buildings were not in stereo on the photos, 2) the farm supported less than 10 cattle, 3) large acreages of land were not on the photorun. In the latter case the farmer was asked his acreage and this was used in place of the measured acreages for testing on the triangle.

The accuracy of prediction of farm types without consideration of the building types is given in Table 12.

TABLE 12

ACCURACY OF FARM TYPE IDENTIFICATION USING CORN-HAY-GRAIN % BREAKDOWN

	TOTAL #	CORRECTLY IDENTIFIED	% ACCURACY
Minor Sample			
	269	237	88.1[4]
Major Sample			
	100	80	80.0
Dairy	43	35	81.4
Beef	57	45	79.0
Major & Minor	369	317	85.9

Upon closer examination the anomalies encountered in the use of the triangle method in the Major Sample Areas tested above were found to represent special cases as noted below.

[4]One should note there is no apparent explanation for the higher accuracy for the minor sample area prediction. It may be that the farmer knows approximately how much of each crop he should have and he assumed he had this when being interviewed. In this way, the farmer may well see his acreages as something different than what they are. (See L. Philpotts, (1966), op. cit.)

Beef - total of 12 anomalies

- 4 part-time farmers
- 5 cow-calf operations - feed beef cows as dairy cows while in calf
- 3 feed beef for others

Dairy - total of 8 anomalies

- 4 part-time
- 1 cash crop emphasis
- 1 holding land for speculative purposes
- 1 has 25 beef cattle in addition to his dairy herd

(all of the dairy farms above have milkhouses)

- 1 buys all of his grain feed.

Only one farm of the above was removed from further testing. The farm thus omitted was the dairy farm being held for speculation purposes.

In that the method appears to be reliable for a large number of cases, in spite of its simplistic nature, a further breakdown was considered. It was decided to attempt to provide a method of separating types of beef operation. This method suffers from the same weakness as does the method proposed by Goodman. It has been derived by simple observation of empirical data.

The types of beef operation were plotted for the major sample areas.[5] The following table was then empirically derived.

TABLE 13

IDENTIFICATION OF TYPES OF BEEF OPERATION

USING THE TRIANGLE DIAGRAM

TYPE OF OPERATION	LOCATION ON TRIANGLE	# AT LOCATION		% ACCURACY
Stockers	over 45% corn	15	(15)	100.0
Beef & Cash and/or Hogs	over 38% grain	20	(20)	100.0
Cow Calf	15-45% corn in Dairy D1 area	7	(6)	85.7
Cow Calf	over 90% roughage	11	(7)	63.6

weighted combined accuracy - 90.6%

excluding the last category - 97.6%

By the time one begins the second stage the farms have been, using the triangle method presented in Fig.4, separated into dairy and beef farm types. The type of beef operation has been correctly identified by the use of the triangle and building analysis.

6.3 Application of the Dairy Crop Model

For dairy cattle one simply converts Table 8 to acreages (as in Table 14) for each study area. If corn is grown and the farm has

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[5]Data for the minor sample area was not complete, and therefore not used in the development of the beef triangle.

TABLE 14

DAIRY ACREAGE REQUIREMENTS

	WENTWORTH	OWEN SOUND
YIELD: Hay	5920	5420
Silage	26200	23600
GENERAL MIX (COWS):		
1. Hay only	.66 acres	.73 acres
2. (Hay +	.49 acres	.53 acres)
(Silage	+.23 acres	+.26 acres)
3. Silage only	.47 acres	.52 acres
GENERAL MIX (YOUNG):		
1. Hay only	.36 acres	.40 acres
2. (Hay +	.27 acres	.30 acres)
(Silage	+.12 acres	+.14 acres)
3. Silage only	.25 acres	.27 acres

The above is simply derived from Table 7, taken in conjunction with the yield values taken from Ag. Stats. op. cit.

All figures are for wintering one animal. If there is not the required acreage of pasture these acreage figures must be manipulated as described in the text.

TABLE 15

DAIRY ACREAGE REQUIREMENTS FOR SETS

		WENTWORTH	HURON
YIELD:	Hay	5920	5420
	Silage	26200	23600
GENERAL MIX (per set)			
1.	Hay only	.95 acres	1.05
2.	Hay +	.71 acres	.77
	Silage	.33 acres	.37
3.	Silage only	.67 acres	.74

The above is derived from Table 14, combined with the assumption that the cow/heifer ratio is 10/8.

silos one then determines how many sets of animals could be fed from the silage available. Following this step one determines how many sets of animals could be fed from the given hay acreage.

This calculation is made on a six month basis if sufficient pasture exists to carry the animals for a summer. The pasture required has been assumed to be one acre per cow and calf together. This assumption is based on the feed value of pasture as well as the fact that pasture will regenerate itself if proper management techniques are used.

The sum of the sets supported by corn and the sets supported by hay yields the number of cattle that could be carried by the feed available on the given farm.

6.4 Application of the Beef Crop Model

The application of the beef crop model is similar to the dairy crop model. The only complication is the determination of type of operation referred to above. One must convert the figures for weight of feed required for beef cattle to acreages. This conversion is made in Table 16.

One simply divides the acreage required for the given operation's animal ages into the feed acreage available. The building capacity analysis is performed in the manner indicated in Chapter V.

In order to facilitate understanding of the methodology used, Charts 3 and 4 apply each step to actual farms drawn from the sample area of Owen Sound.

TABLE 16

BEEF ACREAGE REQUIREMENTS

FOR COWS

	WENTWORTH	WARDSVILLE	HURON	OWEN SOUND
r1	.63 acres	.72 acres	.65 acres	.70 acres
r2	.30H + .23S	.34H + 22S	.31H + 21S	.33H + .25S
r3	.38 acres	.36 acres	.35 acres	.42 acres

FOR YOUNG

	WENTWORTH	WARDSVILLE	HURON	OWEN SOUND
r1	.61 acres	.68 acres	.62 acres	.66 acres
r2	.31S + .10 H	.30S + .10H	.28S + .10H	.34S + .10H

This table is keyed to the roughage mixes listed in Table 9.

H - acreage of hay
S - acreage of corn silage

All figures are acreages for wintering one animal. If no pasture these figures must be doubled.

CHART 3

DAIRY FARM #13 - OWEN SOUND

BARN - 105 x 50 ft. - 2 rows, effective length
78 ft. @ five foot stalls = 16 stalls long
2 rows = 32 cows

\# young = .8 x 32 = 25.6

CROP - 73.4 acres hay
$>$30 acres pasture

hay required per set = .73 acres + .8 (.40) = 1.05

= 70+ sets = 139 cattle

CHART 4

BEEF FARM #4 - OWEN SOUND

BARN - 65 x 48 ft. - 2 rows, effective length
48 ft. @ 4 ft. per stall = 24 stalls
$\therefore$ 24 cows and 24 calves

CROP - 26.6 hay, enough pasture to feed for summer,
require 1.23 acres hay for 1 cow and 1 calf

$\therefore$ can feed $\frac{26.6}{1.23}$ = 21 cows and 21 calves

Total number that could be supported by crops - 42 cattle

6.5 Management of Discrepancies Between Crop and Building Predictions of Livestock Numbers

The number of cattle predicted by the building analysis in the previous charts varies considerably from the number arrived at in the crop analysis. It would appear one farm (#13) produces more crop than is necessary and its buildings cannot possibly accommodate the number of cattle that the crops could support. The other farm (#4) has space in its barns to house more animals than the crops could support. It is the function of step four to reconcile these differences.

If there is a large error one should accept the lower estimate. This assumption relates to the earlier statements concerning the need for both adequate feed and housing.[6] A wide disparity would indicate one or the other of these requirements is not being satisfied.[7]

A problem arises when one is presented with a pair of predictions that are close to each other. A case in point is the beef farm mentioned in Chart 4. A difference of six cattle or 12% exists. No criteria are known to this author upon which to base a selection of an appropriate figure for the actual cattle numbers.

This author has considered the following two points:

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[6] See pages 35 and 54 of this study.

[7] The farmer may have another block of land if the buildings appear to be much too large for the crop capacity. The study at hand has knowledge of such separated blocks, therefore this problem is not considered here.

1. A farmer may, by ignoring minimum standards, place more cattle in a barn than is suggested by the Department of Agriculture, and outlined in Chapter V of this study. Still, there must be a limit on the number of cattle that could be housed in a given set of barns.

2. A farmer may, because of breed, or age distribution, require less feed than the model presented in Chapter IV would suggest he needs.

It has therefore been necessary to create the following arbitrary and artificial criteria for reconciling differences between the crop and building prediction:

1. If the difference between the building and crop predictions is more than four cattle in fifty, take the lower value.

2. If the difference between the building and crop model is less than four cattle in fifty, average the two.

3. If the difference is one animal, take the lower value as correct.

Thus for the example in Chart 3 the figure of 139 is rejected, and the figure of 58 cattle is accepted. Similarly, for the second example, the difference is greater than four in fifty. Therefore the smaller figure of 42 is accepted, while 48 is rejected.

6.6 Statistical Analysis

The application of the procedures described above gives the results documented below.

The statistical analysis following measures the effectiveness of the models developed. A number of questions concerning the effectiveness arises. These questions relate, for the most part, to the assumptions made throughout this study, and their respective validity. These questions may be listed as below.

1. Is the technique of combining crop capacity and building capacity valid? (Table 17)
2. Are the crops and buildings actually inter-related with each other and the livestock carrying capacity? (Table 18)
3. Is the model more accurate for one type of farm operation than another? (Table 19)
4. Does the model vary in accuracy with varying crop yields and in varying localities? (Table 17)
5. Is the model more accurate for larger or smaller farms? (Fig. 7.)
6. Can one establish confidence limits on the accuracy of prediction? (Table 20)

The answers to these questions can be arrived at through simple statistical analysis of the appropriate results given by the models.

From the application of the composite model it is clear that the technique is indeed valid and workable for those farms involved in cattle and cash crop farming.

The component parts of the model, the building capacity model, and the crop capacity model, taken as separate entities are not as accurate as the above composite model. The levels of accuracy of each are indicated in Table 19 below.

TABLE 17*

MEAN AND STANDARD ERRORS OF PREDICTION OF THE COMPOSITE MODEL BY STUDY AREA AND TOTAL SAMPLE

MEAN:		MEAN ($\bar{x}$) %	SAMPLE SIZE (n)
	Owen Sound	-3.5	20
	Wardsville	-1.3	20
	Huron	-0.75	21
	Hamilton	-0.11	20
	TOTAL SAMPLE	-1.4	81

STANDARD ERROR: Standard error given by:

$$\sigma = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n - 1}}$$

where $n = 81$

$\bar{x} = -1.4\%$

$\Sigma (x - \bar{x})^2 = 2976.48$

$\sigma = 6.1\%$

*Taken from Table 21.

TABLE 18

MEAN AND STANDARD ERRORS FOR THE BUILDING AND CROP CAPACITY MODELS

	Mean	Standard Error in %
Building	-3.3%	16.6
Crop	-3.6%	14.3

The high value for standard errors in Table 19 indicate a wide range of errors distributed about the mean error value. The use of the two models together as controls on livestock carrying capacity, as well as controls on each other was earlier assumed to be a valid approach. This two part assumption has now been proved to be valid. Separately, high error values are obtained. Used together much lower errors result.

Also of interest in this study is the accuracy of prediction for each of dairy and beef operations. (See Table 19)

The following diagram, Figure 7, illustrates the lack of relation between the number of cattle on a given farm and the accuracy of prediction. One would assume that accuracy would increase with larger farms, for an error involving a small number of cattle in a small herd would result in a larger percent error than the same number in a large herd. If it were, a curve as shown in Fig. 7 would result (the Y intercept and slope of the line have been arbitrarily selected).

In order to establish confidence limits it is necessary to determine the nature of the distribution of the error value about the

TABLE 19

ACCURACY OF DAIRY AND BEEF PREDICTIONS COMPARED

	$\bar{x}$	S standard error
Dairy	-0.5	7.3
Beef	-1.9	5.9

Assuming there is a difference in the prediction accuracy for each of the dairy and beef populations at 99% confidence, one may use the z - statistic.*

Establishing the null hypothesis H_o: Dairy and beef predictions are different levels of accuracy.

The alternative hypothesis H_A: Dairy and beef predictions are of the same level of accuracy.

At 99% level of confidence

accept H_o if $z > \pm 2.38$

$$\text{where } z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

This method is valid where $n_1 > 30$, and $n_2 > 30$. $n_1 = 29$, this test has been used in that $n_1 \approx 30$, and $n_2 = 52$.

$$z = \frac{(-.5) - (-1.9)}{\sqrt{\frac{53.0}{29} + \frac{34.3}{52}}} = \frac{1.4}{2.49} = +.87$$

$z < +2.38$, therefore the null hypothesis must be rejected at the 99% confidence level. Dairy and beef predictions are the same level of accuracy.

*This test also assumes normalcy of the distribution of errors about the mean. This will be discussed below. The basis for the test performed above is: J.E. Freund, Modern Elementary Statistics, Englewood Cliffs, N.J.: Prentice-Hall, 1967, pp. 254-257.

mean error. The size of the sample, 81, negates directly assuming normalcy,[8] nevertheless one could well obtain a normal distribution of errors if there is no built in flaw in the model. For this reason a simplistic test for normalcy was employed, the cumulative percent distribution on arithmetic probability paper.[9] (Fig. 8)

If the percent of observations less than a given value are plotted as points and "if such points lie very close to a straight line, we consider this as evidence that the distribution follows the general pattern of a normal distribution."[10] The percent error values for the composite model are so plotted.

The subjectivity lies in the definition of very close. The errors cited in the example by Freund, and the nature of the derived error values in this study do, however, lead one to assume that the distribution is close to normal.

A further indication of the power of the composite technique over each of the crop and building capacity measures may be given.

Using the formula given in Table 20, the 99% confidence interval for the crop model error is given by:

$$-7.8 < u < +.6$$

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[8]Freund, <u>op. cit.</u> p. 255.

[9]Its simplicity is noted by Freund (<u>op. cit.</u>) p. 176. He states it "is not the best, it is largely subjective."

[10]Freund, <u>op. cit.</u>, p. 178.

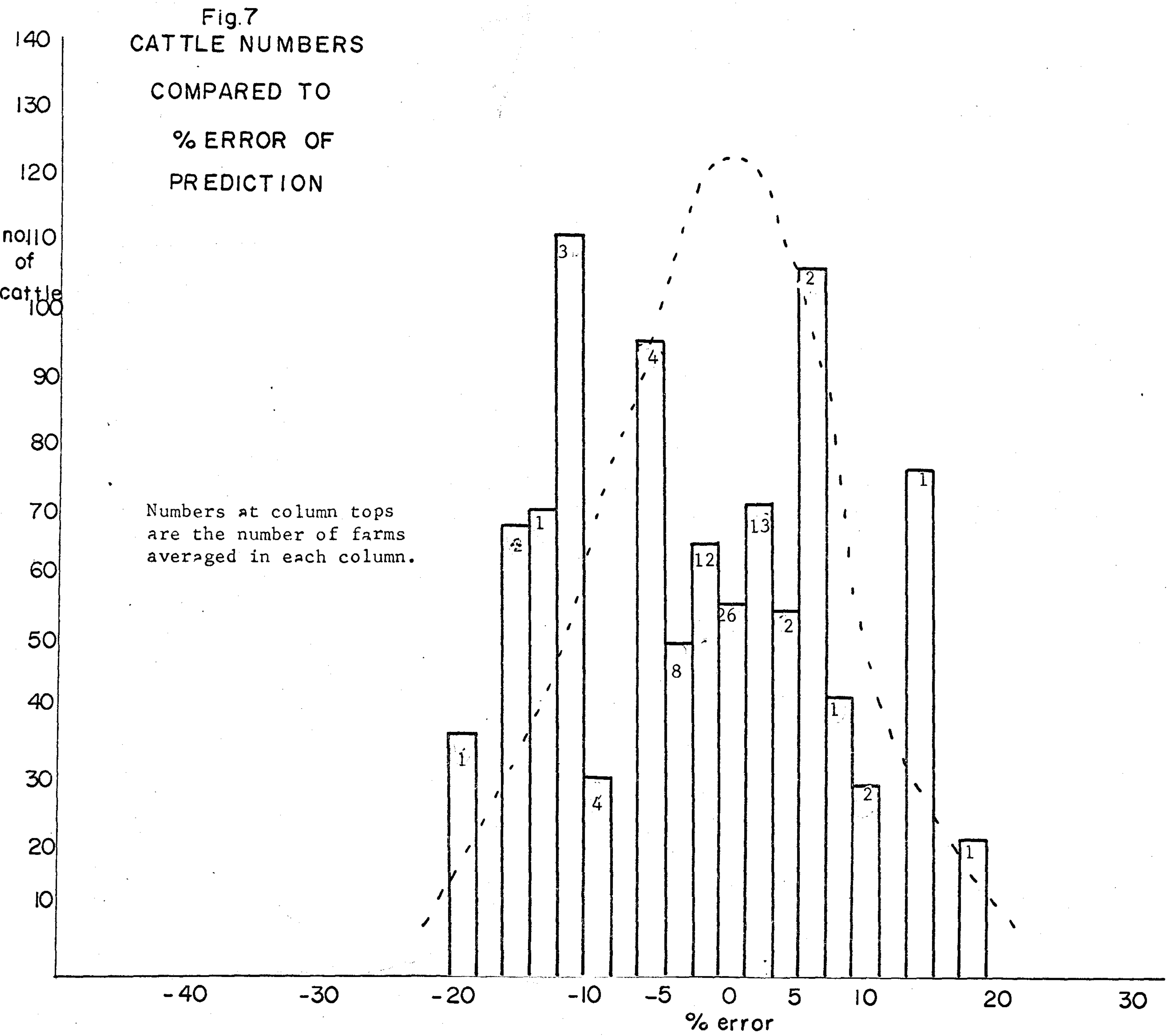

Fig.7 CATTLE NUMBERS COMPARED TO % ERROR OF PREDICTION

Fig. 8

CUMULATIVE ERROR PERCENTAGES:

A TEST OF NORMALCY

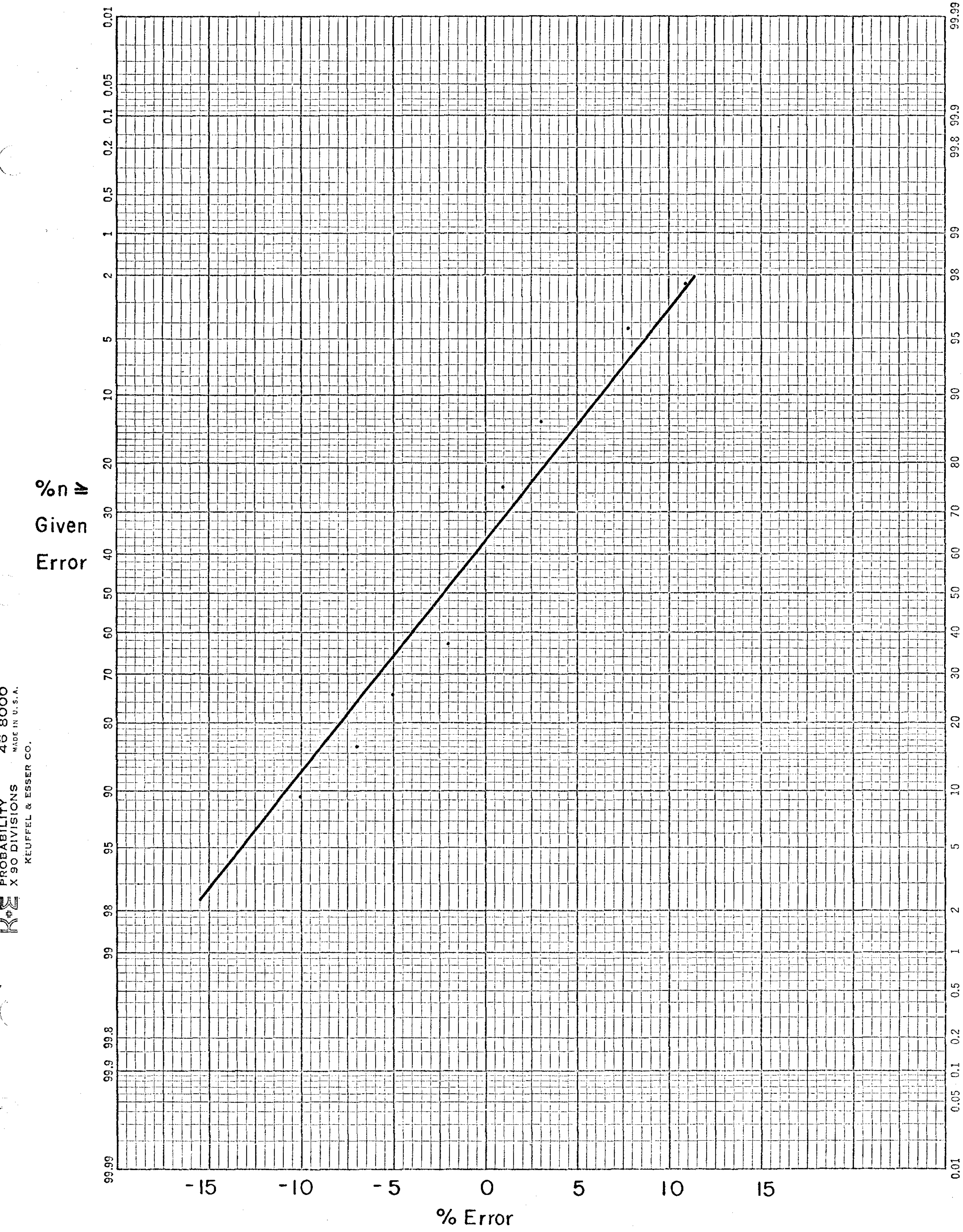

TABLE 20

THE DEVELOPMENT OF CONFIDENCE LIMITS*

The near normalcy of distribution of the derived error values about the mean facilitates the establishment of confidence intervals for the error of prediction of the model.

The 95% interval for the distribution of error values is given by the following:

$$\bar{x} - z_{\alpha/2} \frac{\sigma}{\sqrt{n}} < u < \bar{x} + z_{\alpha/2} \frac{\sigma}{\sqrt{n}} \qquad (1)$$

where: $\bar{x} = -1.4$

$= 6.1$

$n = 81$

and $z_{\alpha/2} = 1.96$

substituting the known values: $-2.73 < u < -.07$

The 99% interval for the distribution of error values is given by the substitution of $z_{\alpha/2} = 2.58$ in (1) above.

substituting the known values: $-3.15 < u < +.31$

i.e., 99% of the time the error will fall between -3.15 and +.31.

*The methodology is taken from Freund op. cit., p. 224.

The corresponding interval for the building model error is given by

$$-8.2 < u < +1.6$$

The confidence limits established above further demonstrate the limitations of one method or another taken by itself. The composite model proved to be much more accurate than either of the above.

The error values that are associated with each of the building and crop models may be inferred to be of two basic types.

First there may be errors in the measurement of acreages or buildings. Second, the farmer may not operate in the manner outlined in the assumptions of the model. A given farmer may not have a milk contract large enough to require a large enough herd to fully occupy his barns, or use his crops to the capacity possible. The farmer may buy crops such as hay, thus contravening the assumption almost all roughage is grown on the farm. The farmer may be older, and slowing down his pace of operation. Another source of error may be the inefficient farmer who, through mismanagement, does not operate to the capacity he could.

Each of the two models does predict, in 32 of 154 cases, the exact number of cattle. Therefore the problems of incorrect measurements and erroneous assumptions may be relegated to a secondary role in providing explanations of errors. If these were important one would not expect such a large number of correct predictions. Therefore it may well be that the errors are a result of inconsistencies in the farmer's method of operation.

6.7 Summary

The other questions put forward on page 80 have been answered in the foregoing analysis. The 98.6% accuracy of the composite model indicates that the method of combining the two models is apparently valid. Further, the accuracy is not apparently related to the type of operation, number of cattle present, or the study area from which the sample has been drawn.[11] Confidence limits have been established for the error of predictions.

All of the assumptions made are not necessarily as accurate as suggested by the results of the composite model. The only assumptions that may be so described are those related to the development of the last stage which served to integrate the crop and building capacity models.[12] It may well be that some errors in the assumptions cancelled each other out. This is not of importance, for the thesis has been satisfied with the development of a model proved to be accurate under the varying controls and influences built in to the selection of the study areas.

The further development of this methodology, to be discussed

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[11]See Table 21 of Data Analysis by Study Area.

[12]The major part of this methodology is not considered to contain the identification of farm type.

in Chapter VII, may result in the removal of the stringent requirements on types of operation that may be analyzed using the current methodology. This study had as its purpose the development of a method to determine cattle numbers on cattle raising and cattle-cash crop farms. Further development has been considered to be beyond the scope of this paper.

In conclusion then, the model is very close to being "representative of the system under study"[13] and the use of panchromatic aerial imagery has been proved to serve as a "mirror of reality"[14]. Cattle type and numbers on individual farms have been measured to a high degree of accuracy.

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[13]R. Chorley and P. Haggett, op. cit., p. 23.

[14]P. Haggett, op. cit., p. 20.

TABLE 21

ANALYSIS OF DATA

HURON

Farm	1	2	3	4	5	6	7	8
1	14		14	0	25	+44.0	14	0
4		107	106	- 9.4	97	-10.3	101	- 5.9
3		43	44	+ 2.3	40	- 7.5	42	- 2.4
2		70	80	+12.5	68	- 2.9	68	- 2.9
10		33	34	+ 2.9	34	+ 2.9	34	+ 2.9
11		120	138	+13.0	123	+ 2.4	123	+ 2.4
16		83	89	+ 6.7	85	- 2.4	87	+ 4.6
21		35	74	+52.7	34	- 3.1	34	- 2.9
23		51	48	- 8.3	52	+ 1.9	50	- 2.0
25		60	60	0	64	+ 6.3	62	+ 3.2
27		120	119	- 0.8	119	- 0.8	119	- 0.8
31		125	123	- 1.6			123	- 1.6
32								
34		67	77	+13.0	67	0	67	0
35	180(75c)		133	-26.1	180	0	180	0
36		77	153	+49.7	77	0	77	0
37		150	124	-21.0	153	+ 2.0	153	+ 2.0
38	60(32c)		64	+ 6.3	64	+ 6.3	64	+ 6.3
40		20	18	-11.1	22	+ 9.1	20	0
41		27	26	- 3.8	26	- 3.8	26	- 3.8
42		70	68	- 3.1	61	-14.8	61	-14.8
46		35	72	+51.4	35	0	35	0
				$\bar{x}$(%E) = +6.3		$\bar{x}$(%E) = +1.4		$\bar{x}$(%E) = -0.75
Standard Error				=21.4		=11.2		

Explanation of Column Headings:

1. Number of dairy cattle on the farm, the number of cows is in brackets "(75)" following this number.
2. Number of beef cattle on the farm of given number.
3. Number of cattle predicted by the building analysis.
4. The error of the building prediction expressed as a percent of the predicted value.
5. Number of cattle predicted by the crop analysis.
6. Error for the crop prediction as in 4. above.
7. Number of cattle predicted by the composite model.
8. Error for the composite model as in 4. above

For columns 4, 6, and 8, the errors are calculated on the basis of the (predicted - actual) divided by (predicted x 100). Thus the errors are expressed as a percent of the predicted.

ANALYSIS OF DATA

OWEN SOUND

Farm	1		2	3	4	5	6	7	8
1	55(35)			36c	+ 2.8	132	+58.3	36c	+ 2.8
2	40(20)		45	42c+34	- 7.1	78	- 9.8	77	-10.4
3	(40) +		120	42c	+ 4.8	156	- 2.6	156	- 2.6
4			41	48	+14.6	42	+ 2.4	42	+ 2.4
6			60	58	- 3.4	70	+ 7.7	58	+ 3.4
8		12		18	+33.0	12	0	12	0
9	75(35)			52c+40	+18.4	84	+ 9.3	88	+14.8
13		57		56	- 1.8	139	+62.1	56	- 1.8
15			60	52	-15.4	140	+57.1	52	-15.4
20	45(25)			26c+20	+ 2.2	86	+47.7	46	+ 2.2
21	50(26)			27c+22	- 2.0	51	+ 2.0	50	0
22	60(29)			36c+29	+ 7.7	58	- 3.4	61	+ 1.7
23			90	92	+ 2.2	85	- 5.9	88	- 2.3
29	76(36)			62	-22.5	68	-11.8	65	-16.9
40			150	133	-12.7	266	+43.6	133	-12.7
28	62(34)			34c+27	- 1.6	60	- 3.3	60	- 3.3
41			60	57	- 5.3	58	+ 3.4	57	- 5.3
62	22(11)			19	-15.8	21	- 4.8	20	-10.0
74	28			24	-16.6	29	+ 3.4	26	- 7.7
89			235	232	- 1.3	286	+18.4	232	- 1.3
					$\bar{x}$ = -2.5		$\bar{x}$ = +13.7		$\bar{x}$ = -3.5

Standard error = 10.3 = 11.2

"c" represents the number of cows predicted using the age ratios outlined in Chapter IV. The number following the "c" represents the number of young cattle predicted.

The errors are calculated on the basis of the (predicted - actual) divided by (predicted x 100). Thus the errors are expressed as a percent of the predicted.

ANALYSIS OF DATA

<u>WARDSVILLE</u>

Farm	1	2	3	4	5	6	7	8
15		18	18	0	22	+18.2	20	+10.0
20		42	50	+16.0	45	+ 7.1	45	+ 6.7
25		36	35	- 2.9	36	0	36	0
26		50	60	+16.3	50	0	50	0
35		19	26	+23.1	19	0	19	0
37		125			124	- 0.8	124	- 0.8
38		15			15	0	15	0
39		80	77	- 3.9	76	- 5.3	77	- 3.9
40		36	28	-28.6	33	- 9.1	30	-20.0
48		43	49	+12.2	38	-13.2	40	- 7.5
49		150	64	- 1.6	160	+ 6.3	160	+ 6.3
54		40			40	0	40	0
55		32			32	0	32	0
66		12			12	0	12	0
68		10	24	+58.3	10	0	10	0
87		49	58	+18.4	48	- 2.1	50	+ 2.0
95		30	54	+41.3	26	-15.3	28	- 7.1
100		72	70	- 2.9	74	+ 2.7	72	0
106		75	66	-13.6	74	- 1.4	70	- 7.4
109		150	108	-11.1	141	- 6.4	141	- 6.4
				$\bar{x}$ = +8.1		$\bar{x}$ = -1.0		<u>$\bar{x}$ = -1.3</u>

Standard Error =22.2 =7.2

Farm #49 keeps only 65 cattle at his home farm

Farm #109 keeps only 120 cattle at his home farm

ANALYSIS OF DATA

WENTWORTH

Farm	1	2	3	4	5	6	7	8
55		400	408	+ 4.5	419	+ 4.5	413	+ 3.1
61	36c		36	0	36	0	36	0
88	25		26	+ 1.4	26	+ 1.4	26	0
91		53	54	+ 1.8			54	+ 1.8
95		30	30	0	26	-15.4	28	- 7.1
98	19		19	0	19	0	19	0
103	40		36	-11.1	40	0	38	- 5.3
108	25		26	+ 1.4	26	+ 1.4	26	+ 3.8
109	18		20	0	20	0	20	+10.0
111	45		46	+ 2.2	46	+ 2.2	46	+ 2.2
112	22		27	+18.5	27	+18.5	27	+18.5
113	20		18	-11.1	20	0	19	- 5.2
114	17		16	- 6.2	16	- 6.2	16	- 6.2
117		40	47	+14.9	36	-11.1	36	-11.1
118		41	41	0	42	+ 2.4	41	0
119	30		30	0	30	0	30	0
120	40		38	- 5.3	40	0	39	- 2.6
123		110	110	0			110	0
127	26		24	- 8.3	26	0	25	- 4.0
128	20		39	+48.7	20	0	20	0
			$\bar{x}$ = +2.4		$\bar{x}$ = -0.1		$\bar{x}$ = -.11	

Farm #112 has room for 25 cattle

Farm #128 has room for 40 cattle (stated in interview he was operating at 1/2 capacity).

CHAPTER VII

TESTING OF SECONDARY ASSUMPTIONS

It has been assumed that the photography used in this study is indeed suitable, both as regards scale and type of imagery. One may, however, question the possible effects of using a larger scale or different imagery.

The number of researchers who advocate the use of color imagery for agricultural studies[1] would tend to support the inference that the use of color imagery would also result in higher levels of accuracy. Unfortunately, the color imagery used in this study, is also of a larger scale.

It was decided to test the accuracy of prediction for the area with the large scale color photography against an area of similar farm types, the areas being Huron and Wardsville respectively.

From the assumptions above one would assume that the accuracy for the Huron area would be higher. That is the mean error values for the two areas would not be equal.

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[1]See Colwell (1960) op. cit.

Null hypothesis H_o: $\bar{U}_H = \bar{U}_W$

Alternate hypothesis H_A: $\bar{U}_H \neq \bar{U}_W$

Test using $t = \dfrac{\bar{X}_1 - \bar{X}_2}{\sqrt{\dfrac{\Sigma(X_1 - \bar{X}_2)^2 + \Sigma(X_2 - \bar{X}_2)^2}{n_1 + n_2 - 2} \left(\dfrac{1}{n_1} + \dfrac{1}{n_2}\right)}}$

where: $\bar{X}_1 = -1.3$

$\Sigma(X_1 - \bar{X}_1)^2 = 855.16$

$n_1 = 20$

$\bar{X}_2 = -0.75$

$\Sigma(X_2 - \bar{X}_2)^2 = 384.53$

$n_2 = 21$

$t = -.3107$

From Freund (op. cit.) the null hypothesis cannot be rejected at any degree of confidence. Therefore one must accept the null hypothesis. Therefore one must conclude that there is no appreciable increase in accuracy using the larger scale color imagery.

From the above one may state that the assumptions made in Chapter III concerning scale, and the use of panchromatic aerial imagery in place of color are supported. The use of color adds no more accuracy to the composite model, nor does the increase in scale.

The use of color imagery in this study has been qualitatively assessed to be of more value by this author in the preparation of this study in the following:

1. separation of crops is made faster;
2. one may more easily see manure piles, etc., to identify active farms;
3. stock yards are more easily identified;
4. sharper definition and less shadow for building measurement;
5. farm boundaries are more easily inferred.

The above five comments cannot be measured in terms of accuracy, and unfortunately actual information on time factors, etc., was not recorded. These peripheral comments on scale and type of imagery do not directly affect the accuracy of the methodology herein presented. Their consideration in depth may be easily accomplished before operationalizing the techniques of interpretation of livestock numbers on a practical basis.

One may conclude, however, that the methods presented are indeed workable at the scale and type of imagery used.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The development of a model to predict type and number of cattle on a given farm was set out as the goal for this study. This has been accomplished. The model has proved to be "workable" and, although based on simplistic assumptions, it has proved to be able to "mirror reality".

It was developed as a simplistic exploratory model to test the validity of using features that may be easily interpreted or read from aerial photographs to draw inferences concerning features not easily measured. The validity and applicability to real world situations have been demonstrated.

The success of the model is in part a function of the limitation set on the range of farm types to which the model has been applied. The only livestock farms considered were those involving cattle.

The success of the model does, however, lend credence to the basic assumption stated earlier that "aerial photographs are a useful means of collecting data on agricultural land use".

The specific aim of the study was to provide a model capable of "predicting, to a high degree of accuracy", the type and number of cattle on a given farm". This has been accomplished with a mean error of -1.4% despite the fact that a few small problems have been referred to in Chapters VI and VII.

The model was developed in three subsequent stages in Chapters IV, V, and VI respectively. The analysis to test the accuracy of the total approach and its component parts, as well as the accuracy of the assumptions made was carried out in Chapter VI.

A number of assumptions have been made in this study. Most[1] have proved to be valid. On page 14 the distinction was made between "external" and "internal" variables. It was assumed such criteria as local environment, mechanization, areal differences in environment, and a farmer's attitudes would, as internal variables, be reflected in the external variables. These external variables were defined as cropping techniques, yields, and building layouts.

These external variables were considered to be inseparable in their inter-relationship in determining the actual numbers of cattle. Further these external variables were considered to vary with type of operation.

The accuracy of the overall, or composite model, and the accuracy levels of prediction for both dairy and beef farm operations lead one to conclude that these basic assumptions are indeed valid.

It was assumed that the roughage mixes would be of adequate range to be suitable for the entire area under study, and for farms of varying size, or scale of operation. The accuracy of farm type identification and the apparent lack of relationship between cattle

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[1]Some assumptions, by their nature, could not be tested. The assumptions most open to debate, and requiring more work centered around the farm type identification.

numbers and accuracy of prediction (Fig. 9) supports the above implied assumptions. Further, confidence intervals for the error of prediction have been established. These may, however, vary in areas more remote than those used in this study.[2] In such cases farmers may not be following the Ontario Department of Agriculture's guidelines.

Inferences made on page 19 and stated more concisely than the above, must also be accepted as valid. One should note, however, that some of these were also based, in part, on earlier work in air photo interpretation. Thus these assumptions are not considered to require formal proof as do some of the other assumptions made in this study.

On page 22 it was assumed that the scale of 1:12000 would suffice for accurate measurement. One may note that no constantly large error is evident in the errors of prediction. If a measurement was consistantly wrong, or, for that matter, if any one inference was erroneous, one would expect a larger error related to farm type, feed mix used, study area, or size of herd, depending on the source of error. No such errors were found.

A check on the accuracy of scale and the results using color (page 96) support the assumption that the scale of 1:12000 of panchromatic aerial imagery (page 22) in conjunction with the given instrumentation, could not be improved upon. Accuracy levels are not increased by the use of larger scale color imagery such as was used in

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[2]An area considered to be more remote would be the Renfrew County area.

this study.

There are however, errors in the prediction. These may relate to the assumptions previously noted as being weak. The major assumption so identified was that a farmer's attitudes are reflected in his method of operation, i.e. the external controls or variables. This may provide an opportunity for further analysis. A second set of assumptions that may prove to be incorrect are related to farm type identification using the triangle method. First, the farm type boundaries on the triangle (Fig. 4) may in fact vary from county to county as yield values vary. It was assumed that these were constant (page 34). Second, it was assumed a first order nearest neighbour analysis, in conjunction with the location of the guide farms (page 34), would indicate the farm type of a given farm. The need for a more thorough analysis has been recognized, but was considered beyond the scope of this study.

Thus, for the most part, one may conclude that the assumptions upon which this study has been based have been proved to be valid in the context of their applicability to a wide range of farm types in southern Ontario.

The uses of aerial photographs for visual crop inventories have been used successfully by a number of authors mentioned in the discussion of the literature. This study has attempted to go beyond the measurements of the "purposeful tending of crops".[3] A methodology has been

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[3]H. H. McCarty and J. B. Lindberg, A Preface to Economic Geography, Englewood Cliffs, N. J.: Prentice Hall, 1966, p. 204.

presented that utilizes the speed and ease of aerial survey techniques in measuring the other component of agriculture, that being livestock.

Despite the problems that have been encountered, and the need for making a large number of assumptions in this study, the methodology presented herein has proved to be successful. It is the hope of this study that the methodology developed in this study may serve as a basic tool in the collection of agricultural data, as well as a step in the direction of more complete use of aerial panchromatic imagery in agricultural data collection.

GLOSSARY OF TERMINOLOGY[1]

*indicates a term defined elsewhere in the Glossary

Animal Husbandry - a sub-discipline of Agronomy dealing with the raising and caring for livestock.

Beef Farms - all or almost all of the livestock are raised for beef.

Bunker Silo - a method of storing roughage* or succulent* feeds, usually an earth surrounded area with wooden support posts, lined with plastic and covered (sealed) with plastic.

Carrying Capacity - the number of cattle on a given farm expressed in head per workable* acre.

Cach Crop Emphasis - crops are sold instead of fed.

Concentrate - source of proteins, nutrients and laxative used to supplement roughages. Usually composed of grains and/or beans and their derivatives.

Dairy Farms - all or almost all livestock are dairy.

Dry Hay Yield - all hay yield figures are based on dry hay. When harvested hay contains varying amounts of water. The dry hay figures give a means of comparison that is standard.

Farm Management - sub-discipline of Agronomy dealing with the actual management and economics of a given farm operation.

Feed Lot Operation - beef cattle (steers) kept and fed in a small area, much feed is purchased.

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[1]All definitions are consistant with the literature, or with common usage by the farmers in southern Ontario.

Fodder Corn - same as ensilage corn - corn stored in a silo and fed as a succulent* feed.

Level of Mechanization - the extent to which manual labor has been replaced by motive power.

Milkhouse - appendage on the barn that serves to house bulk cooling and storage equipment for fluid milk (cost of outfitting runs up from $10,000.)

"O-Graze" - the technique of cutting the pasture daily and bringing the cut grass and legumes to the cattle.

Open Housing - barn set up where cattle are loose but there are no stalls.

Open Stall - same as above, except with stalls.

Pasture (improved) - land pastured (grazed) that is worked every five to ten years, and fertilized yearly, or nearly so.

Pasture-Reliance - the use of pasture feed to the exclusion of all other feed when pasture available. The usual season is from May to October.

Recommended Feeding - the feed mixes and weights of them suggested by the Ontario Department of Agriculture for various types of livestock.

Roughage - that material that make up the bulk of the cattle's intake in feed. Pastures and hay are considered roughage.

Rough Pasture - generally poor land made so by boulders, slope, creek flats, etc. Only use is for low yielding pasture.

Staunchion - a method of housing cattle (usually dairy) with steel piping adjusted about the cow's neck to hold it in the stall with a minimum of movement.

Silage - material put in silos for storage as succulent feeds.

Succulent Feeds - refers to those feeds put in silos (e.g. ensilage corn) and fed as a wet feed.

Workable Land - that land which may be tilled by modern methods, and machines.

APPENDIX A

QUESTIONNAIRES

The reader should note that the questionnaires presented were developed to collect data for more than the research in this study. Thus some information is of questionable relevance to the current study.

1968 QUESTIONNAIRE[1]

The questionnaire was a loose structured one to allow freedom of expression on the part of the interviewee. The interviewer was dressed in farm clothes with a university jacket to provide initial identification. At all times the interviewer was sympathetic to all of the farmer's problems.

The stated purpose was "I'm doing research in this area for McMaster University in farm operations on how you do things on the farm. Could I have 3 minutes of your time to help me in an essay? I know you are busy with ---- (fill in appropriate farm operation)." If refusal initially the idea of questions was dropped and the interviewer would enter a conversation on the latest farm problem (e.g. the price of corn going down). The questions would be inserted into the conversation, and recorded after leaving the farmstead. This method was time consuming, however the bias away from those who refused was reduced.

THE QUESTIONS:*

(A) 1. When do you plough?

2. How far apart are your dead furrows?

(B) 1. When you sow grain do you go up and down the field or around?

2. Do you use a cover crop (protective crop) when you seed down (sow hay)? What is it?

(C) 1. Do you have tile drainage? How much?

2. Do you spray your grains?

3. What do you use your manure on?

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[1] Source: R. A. Ryerson, op. cit. p. 82.

*NOTE: The questions are phrased for the farmer, in common farm terminology. The interviewer set out to first become trusted to ensure that an interview begun would be finished. For this reason "jargon" was employed.

(D) 1. What method do you use to harvest-grain? How wide a swath?
- hay? " " " " ?

2. Is it "custom done" (done for the farmer by someone else for a fixed rate)?

(E) 1. Where do you keep your cattle in winter?

2. What type of stable set-up do you have? (Pole barn, free-stall, staunchion, etc.)

(F) 1. How many people work this place?

(G) 1. How many acres do you have all told?

2. How much is workable?

3. Do you use any of your unworkable land for pasture?

4. How many acres in each crop?

(H) 1. How many livestock do you have? (Beef? Hogs? Dairy? etc.)

1969 QUESTIONNAIRE

I EQUIPMENT

1. What type of equipment did you use in 1967 for: Corn?
   Grain?
   Hay?

   (Custom or owned, and width)

2. How old would that machinery be - each piece?

3. Which do you crop first - headlands or main crop? - up and down or round and round? Why?

II FEEDS

1. How much corn was used for silage in 1967?

2. Did you buy any (1) Hay? (2) Grain? (III) Other? How much?

3. Did you sell any?

III BARNS

1. Do you have the use of any barn other than those on the home farm?

2. If so, where are they located?

3. What type of stable set-up do you have?

4. If not loose, how many rows of stalls?

5. Is your barn open? Semi-open? Closed type?

6. Do you feel the barns are used to capacity - if not, how many could you carry?

IV

1. Have you had any big changes in your farm operation since 1967?

V LIVESTOCK

1. What breed were you carrying in 1967?

(a) Beef

1. What type of operation was this - feeder, baby, dual purpose, feeder, feed-lot or stable, stockers, etc.?
2. How many were you carrying?
3. How many would have been - calves, yearlings, steers, cows, bulls, feeders?
4. When do you hold cattle?
5. How long would you keep cattle on pasture? (When to when?)
6. How many do you sell each year? (quantity sold together)

(b) Dairy

1. How many would you have had in total?
2. Can you break that total down - calves, heifers, cows (milkers)?
3. Given your acreage and stable set-up how many could you carry (without quotas, etc.)?
4. What type of operation - is this a fluid, industrial or crean operation?

(c) Pigs

1. How many (1) Sows? (2) Weiners? in 1967 and now.

VI DRAINAGE

1. Have you any tile drainage? How much? (/ no. of fields)
2. Was this a good idea in terms of yield?

APPENDIX B

FARM TYPE AND RAW ACREAGE DATA

FROM INTERVIEWS AND MEASURED FROM PHOTOGRAPHS

Much information available has been omitted for the data are not directly relevant. Further, actual cattle numbers are given in Chapter VI, these figures, therefore, have not been included here.

All acreage values have been rounded from the nearest 1/10 to the nearest acre for clarity of presentation.

HURON

FARM #	TYPE[1]	CORN	GRAIN	HAY	PASTURE	ROUGH PASTURE
		ACREAGE				
1	D-C		46	18	15	
4	B-S	24	57	14	17	
3	C-cc		18	5	27	
2	B-C		81	11	7	
10	B-cc	20	40	44	8	
11	B-C-S	83	70	6	8	
16	B-C-S	128	119	30	12	30
21	B-C-cc	14	38	39		
23	B-C-S-H	30	34	13	12	
25	B-D-C	11	18	23		5
27	B-D	35	13	43		12
31	B-D		78		63	
32	D	6	19	5	22	13
34	B-C-S	53	110		31	2
35	D	52	44	72	142	5
36	B-H	233	28		27	
37	B-C	103	49	20	6	5
38	D-C	22	55	52	6	
40	B-H		50	8	14	
41	B-H	12	55	40	53	
42	B-S	45	63	32		
46	B-cc	5	39	5	26	

[1]Type of Operation:
D - dairy
D-C - dairy and cash crop
B - beef
B-C - beef and cash crop
B-S - steers
B-cc - cow calf
H - farm includes hogs
pt - part time

HAMILTON
(WENTWORTH)

FARM #	TYPE	CORN	GRAIN	HAY	PASTURE	ROUGH PASTURE
		ACREAGE				
55	B-pt	225				
61	D	45	58	31		
88	D	35	71	56	19	
91	B-pt		30			58
95	B-C		50	2		10
98	D		27	53	8	2
103	D	16	26	41	16	
109	D		63	20	12	44
111	D-C	37	85			
112	D	9	23	53	8	1
113	D	43	50	34	23	
114	D	27	5	50	4	2
117	B	31	23	50	11	
118	B-C	34	19	4	10	27
119	D	22	46	122	22	2
120	D-pt	7	10	43	15	4
123	B				129	32
127	D-pt	7	13	21		27
128	D-H	46	21	39	12	8

OWEN SOUND

		ACREAGE				
FARM #	TYPE	CORN	GRAIN	HAY	PASTURE	ROUGH PASTURE
1	D	8	34	78	4	74
2	D-B-pt	6	27	42	23	31
3	D-B	2	26	99	60	112
4	B-pt			27	11	58
6	B-pt	6		35	31	20
8	B-pt	2		17	5	
9	D	42	79	69		10
13	D		17	73	17	38
20	D	8		85	25	
15	B-pt		3	86		88
21	D		6	41	15	
22	D-pt	22	22	20	11	
23	D-B	9	52	30	69	15
29	D		31	130	17	
40	B-pt	55	120	200	100	
28	D		26	69	11	6
41	B	5	6	29	28	
62	D		12	12	21	69
74	D	6	25	38	24	88
89	B	30	90	150		396

WARDSVILLE

FARM #	TYPE	ACREAGE				
		CORN	GRAIN	HAY	PASTURE	ROUGH PASTURE
15	B-C	59	21	6		
20	B	38	11	30	13	
25	B	22	14	22		
26	B-C	131	37	21.6		
35	B-H-C	60	97	21		
37	B-C	60	50	17	25	
38						
39	B-C	102	9	12	30	25
40	B-C	7	13	14		30
48	B	70		102		
49	B	80		35		
54						98
55	B	12	6	21	9	116
56	B-H-C	36	16	3	11	26
68	B-C	55	26	6	16	
87	B			30	70	
95	B	16	9	13		16
100	B	114	5	28	75	
106	B-H-C	14	5	21	80	
109	B-H	40	8	16	100	

*Data Incomplete

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