A SAMPLING METHOD
FOR THE STUDY OF RURAL LAND USE

A Thesis

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Preface

This Thesis would hardly be complete without some acknowledgment of the generosity of friends and colleagues, whose ideas, criticism, and assistance added much to the pleasure of the investigation and to whatever value the results may have.

Particular credit should be given to Professor J.Ross Mackay, for originally suggesting the hexagonal sampling system, the form of the tests of sampling accuracy, and, in general, the broad outlines of the investigation. Throughout the course of the study he was more than generous with his time and encouragement, and his irrefutable (if sometimes irritating) logic prevented more than one false step.

Many thanks are due as well to Professor F.K. Hare, for shepherding the manuscript through its final checking; to Mrs. Weldon, an indefatigable typist; to John Tremblay, for his fine reproduction of the maps and diagrams; to G.H. Lash, for ironing out some troublesome passages; and, of course, to the hospitable and understanding people of Huntingdon and Chateauguay.

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Chapter I

THE PROBLEM AND DEFINITIONS OF TERMS USED.

The land use survey is becoming an increasingly important item in geographic studies. This is especially so when such studies are undertaken for the solution of land use problems, because a knowledge of the present use of the land is usually deemed basic to efficient physical planning.

Canada has many land use problems which need to be solved if the natural resources of the nation are to be conserved for the welfare of present and future generations. But Canada is a country of wide extent and scattered population, so that her geographers, few in number, need to find some method of survey which will enable them to study large areas with a minimum expenditure of time and money.

Reconnaissance methods of survey do not furnish adequate information for this task; detailed methods are too time consuming and laborious to achieve economical coverage of the vast areas that require study. Intermediate methods, by combining rapidity of survey with sufficiently detailed findings, might help solve this problem. Few such methods have been developed, however, and of those that have, still fewer can be applied to Canadian needs.

I. THE PROBLEM

Statement of the Problem. It was the purpose of this study (1) to devise, for the study of rural land use, an objective sampling method which would combine rapidity of survey with accuracy of results; (2) to test the method in a rural area of varying physical characteristics; (3) to determine the accuracy of the results by comparing them with census data and by other means; (4) to test the applicability of the results to land use analysis; (5) to draw conclusions concerning the effectiveness of the method as a rapid means of survey and its suitability to the study of various areas.

Importance of the Study. The idea of sampling is by no means foreign to the field of geographic technique, although there are few instances in which sampling has been used as the backbone of a land use survey. Notwithstanding the fact that sampling is saving of both time and expense, such methods have been considered inadequate for land use studies because the accuracy of the interpolated results may be open to doubt. In this thesis, an attempt has been made to develop a method of sampling which will give, in specific situations, results of ascertainable accuracy.

The few available intermediate methods of land use survey have been designed mainly to meet the needs of specific studies. As such, they are not always capable of application to the areas of differing physical characteristics. In this study, however, an endeavour has been made to evolve a method which is inherently applicable to dissimilar regions and problems. Furthermore, it will appear that proper application of the method tends to minimize subjective judgments on the part of the observer. For this reason, the method may prove useful even in cases where considerations of time and expense are unimportant.

II. DEFINITIONS OF TERMS USED

Rural and Urban Land Use. Obviously no hard and fast line of distinction can be drawn between urban and rural areas, or between the kinds of use to which each is put. "Rural" and "urban" are concepts of such a general nature that many criteria might be used to differentiate between the two: the overall aspect of the landscape, the concentration or dispersion of population, or the nature of productive activity.

In this study, the term "rural land use" has been defined as comprising six types of use, all of which are more or less characteristic of the countryside. The six are: cultivated land, rough pasture, areas of natural vegetation, rural built-up areas, waste land, and idle land.

Land Use Survey. The process of surveying and mapping the details of different land uses within any given area has been termed "land use survey" for the purposes of this report. This is a broad definition, for depending on the purposes of any particular survey, there will be considerable variation in the manner of classifying land uses, the accuracy of mapping land use boundaries, and the amount of detail provided.

Detailed Surveys. Detailed surveys may be recognized by several characteristics which they have in common. They provide complete coverage; that is to say, no part of the total area being studied is left uninvestigated. Furthermore, every part of the area is uniformly treated, and usually land use and physical conditions are recorded in much detail. Such a study provides in itself a complete and accurate representation of land use data, and does not require supplementation from other sources. The method by which the survey is conducted, however, is usually slow and expensive.

Reconnaissance Surveys. In general, surveys of the reconnaissance type do not involve detailed investigation of any large part of the total area. Rather, a broad understanding of land use is sought, in many cases for the purpose of supplementing information which has been gained through interpretation of statistical data, or from other sources. While reconnaissance studies do not in themselves form an adequate basis for a full analysis of land use, the methods used make it possible to cover large areas within limited time intervals.

Intermediate Surveys. An intermediate survey has characteristics which lie between those of the detailed study and those of the reconnaissance type. Ideally, an intermediate investigation provides complete coverage, although every portion of the area does not necessarily receive uniform treatment. The primary basis for the understanding of land use is provided by the survey itself, although other sources may be useful to supplement and expand the results of the field work. However, the method contains some of the time and expense saving elements of the reconnaissance survey.

<u>Survey Method</u>. The field procedures used for the collection of land use data, and the manner in which the data are transformed into final form in the shape of maps and reports, are together defined as "survey method" in this study. The survey method is in large degree independent of the classification of land uses which may be adopted for the purposes of any particular report.

<u>Sampling Method</u>. Any survey method which relies on the detailed study of portions of the total area being investigated, whether by means of blocks, typical areas, or sample farms, has been defined as a "Sampling Method" in this thesis.

<u>Hexagonal Sampling System.</u> The particular sampling method which has been developed in this thesis, as distinguished from other sampling methods, is defined as the "hexagonal sampling system". A number of additional terms have been adopted for convenience in describing the mechanics of the system, but their definition has been deliberately reserved for Chapter IV, which concerns the theory and description of the hexagonal sampling system.

<u>Terrain Type and Land Type.</u> Although the term "land type" is widely employed in geographic literature, it has not been used consistently. In the scale of physiographic description, the "province" is followed by the "Section", which in turn is followed by the "land type". On a still smaller scale, however, are the ultimate units of physiographic homogeneity, and the term "land type" has sometimes been applied to these units. In this investigation, it has been necessary to distinguish clearly between the two. For this reason, the term "land type" has been reserved for the description of areas next in order to the physiographic section, while the term "terrain type" has been applied to the individual units which go to make up each land type.

III. ORGANIZATION OF THE REMAINDER OF THE THESIS

The next two chapters of this thesis are concerned with a discussion and analysis of land use survey methods, with particular reference to those of the sampling variety. The advantages and disadvantages of various intermediate methods are discussed, and some theoretical and practical requirements for a successful method are developed.

Separate chapters are devoted to the description and theory of the hexagonal sampling system, and to its test application in a rural area. Following a discussion of theory, the Huntingdon-Chateauguay test area is described, and the details of field techniques used in the study are given.

In the final group of chapters, the quantitative results of the test application are presented, their accuracy is discussed, and the data are applied to different types of land use analysis. The last chapter summarizes the conclusions of preceding chapters and deals with the applicability of the hexagonal sampling system to land use studies in various areas.

Chapter II

THE PLACE AND PURPOSE OF INTERMEDIATE METHODS IN LAND USE SURVEY.

This chapter presents a discussion of selected examples of reconnaissance and detailed methods of land use survey, because an understanding of them is necessary to determine and define the purposes for which intermediate methods are designed.

This discussion is presented in the light of those factors which tend to influence the surveyor's choice as between reconnaissance and detailed methods. The choice of a method for any particular survey will depend upon several factors: the objectives of the survey, the nature and extent of existing data, and considerations of time and expense. In the following discussion, each of these factors serves as a main heading under which specific methods are examined. In this way, the need for intermediate methods is explained, and conclusions are reached as to what results they should be expected to produce.

I. THE FACTOR OF SURVEY OBJECTIVES

It is not necessary, within the scope of this thesis, to discuss in detail the effects of survey objectives in governing the choice of method.[1] Usually the choice will not be restricted to any extent, except in cases where a practical program for the improvement of land use is envisioned. As one authority has stated, ". . . as soon as land planning work leaves the theoretical plane, and the problems assume practical application, minute detail is essential."[2] Thus, in the surveys of the United States Soil Conservation Service, where the objective is the re-planning of individual farms, the work is done on a detailed, field-by-field basis.[3]

By no means all surveys have purposes which limit methods to the detailed variety, however. Numerous examples might be cited in which the objective was the delimiting of land classes on a broad basis. The United States Resettlement Administration, for instance, successfully mapped land use in several western states for the purpose of ascertaining ". . . the pattern of present land use as an aid to land use planning . . ." on the basis of statistical data.[4] In general, when the objective is the delimitation of land use classes on other than a detailed basis, the choice of method is likely to be influenced less by the purposes of the survey than by other factors.

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(1) On this particular point, the two most useful references are: G.V.Jacks, Land Classification for Land Use Planning, and U.S. National Resources Planning Board, Land Classification in the United States.

(2) K.C.McMurry, cited by C.C.Colby, in "Changing Currents of Geographic Thought in America," Annals Assn. Am. Geog., 26:32, 1936.

(3) Jacks, op.cit., p. 45.

(4) U.S.National Resources Planning Board, op.cit., p. 31.

II. THE FACTOR OF EXISTING DATA

The availability and nature of existing land use data may well be the deciding factor in the choice of method for any particular survey. Such information is usually in statistical form, but the figures may be given either for large areas such as counties, or for small areas such as census subdivisions within counties. Furthermore, it is not possible to assess the relation of land use to physical conditions on the basis of statistical material alone; for this purpose, some field work is necessary.

If, for example, a county is to be surveyed, and land use data are available for townships within that county, it will be possible to plot the general distribution of such items as crops, forests, and pasture lands without any field work being necessary. The study will be further simplified if information on physical conditions is available, such as that provided by detailed soil maps and topographic sheets. When all of these types of data are available in large amounts, a reconnaissance survey of the area may well be sufficient for a general study of land use in the area.

Pennsylvania Reconnaissance Survey. A reconnaissance land use survey of the entire state of Pennsylvania used existing data as its basis. The lands of the state were grouped into six classes according to their suitability for agriculture, and a map of the land classes on a scale of eight miles to an inch was produced.(5) The basic classification was worked out from census returns for minor civil divisions. After plotting this data,

> . . . the boundary lines between land classes were smoothed by reference to soil maps, topography sheets, road maps, or other available data. Then the resulting map was shown to county agricultural agents or other people familiar with the various counties and their criticism obtained as to the proper location of the lines. (6)

<u>A Reconnaissance Study of Quebec.</u> Reconnaissance studies are not intended to take the place of detailed land use surveys, nor can they, in fact, yield much information when the type of data employed in the Pennsylvania survey is not used or not available. Blanchard carried out a broad reconnaissance study of the central settled portion of Quebec without recourse to detailed census material. The volume is not intended to be solely a study of land use,(7) but about one hundred of the five hundred and seventy-seven pages in the work are devoted to observations of this category. Only one map of land use - - a dot map by counties of the distribution of dairy cattle - - was included, and the descriptions of land use are of a very general nature and unsupported by detailed studies.

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(5) "Reconnaissance Land Utilization Map of Pennsylvania," <u>to accompany</u> P.J. Wrigley, <u>Land Use in Pennsylvania</u>.

(6) P.J. Wrigley, personal communication, 4 May 1948.

(7) "Région du fleuve Saint-Laurent, Cantons de l'est, Laurentides, tels sont les trois districts, peuplés en tout de 743,000 âmes en 1931, dont l'on va s'éfforcer, aux cours de ce volume, de décrire le paysage et d'expliquer les traits, physiques autant qu'humains." Raoul Blanchard, <u>Le Centre du Canada Francais</u>, p.2.

III. THE FACTOR OF TIME AND EXPENSE

Where more information is desired than can be obtained by reconnaissance methods, a detailed survey may be considered as an alternative. Detailed work, however, is time consuming and expensive, as the following examples will illustrate.

The Use of Detailed Methods in Great Britain. The Land Utilisation Survey of Great Britain stands as a monumental example of the use of detailed methods.[8] The report documents land use for the whole of England and Scotland in nine volumes and more than two hundred map sheets on a scale of one inch to one mile.

For this survey, the land use in each separate field was recorded. Some idea of the amount of work involved in such an investigation may be had from Stamp's original estimate of this factor:

> The survey is to be carried out on the 6 inch Ordnance Survey maps, as on these maps each individual field is marked. There are roughly 22,000 quarter sheets to be covered, each six square miles in area, and requiring two or three days' work on the part of the volunteer surveyor.[9]

From the point of view of cost, it was fortunate that Stamp was able to conduct the survey on a voluntary basis by using the existing organizational network of the British school system.

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(8) L. Dudley Stamp, editor, The Land of Britain: The Report of the Land Utilisation Survey of Britain.

(9) L. Dudley Stamp, "The Land Utilisation Survey of Britain," Geog. Jour., 78:41. 1931

Detailed Surveys in New York State. The land use studies of New York, conducted by the Department of Farm Management and Agricultural Economics of the New York State College of Agriculture, are also on a detailed basis. Here the unit parcel of land was a ten acre square, within which the surveyor recorded the predominant land use, as well as secondary uses and the condition of farm buildings. These studies resulted in a land class map for each county surveyed, giving a detailed picture of the distribution of six land classes, each of which was graded according to its suitability for different types of use.(10)

The entire area of each county studied was covered in this manner. The work was started in 1930, and by 1939 had resulted in detailed reports for fourteen of the fifty-five agricultural counties in the state.(11) No breakdown of the cost of these surveys is available, but the first appropriation (which apparently was supplemented considerably at later dates) was for ninety-six thousand dollars.(12)

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(10) A.B. Lewis, Methods Used in an Economic Study of Land Utilization in Tompkins County, New York, and in other Similar Studies in New York, p. 28 ff.

(11) V.B.Hart, Land Use in New York, p. 10.

(12) A.B. Lewis, op.cit., p. 15.

IV. CHOICE OF METHOD INFLUENCED BY A COMBINATION OF FACTORS

In many cases, all the factors bearing upon the choice of method will come into play, so that neither reconnaissance nor detailed methods suit the requirements of the study. This is a common problem in Canadian land use surveys, as the following example illustrates.

A Hypothetical Example. For purposes of discussion it is assumed that a land use survey of a typical Quebec county is contemplated. The county has an area of about four hundred square miles, and is divided into ten census subdivisions. Detailed soil surveys have not been made, although topographic maps and air photographs are available to supplement the data obtainable from census reports.

Plotting the census data, by standard isopleth methods, will give boundary lines which can be placed in an approximate fashion, but these boundaries may not in fact represent significant divisions between different land use areas. With information on soil conditions lacking, only the roughest correlations can be made (by the use of aerial photographs and topographic maps) between land use and physical conditions without embarking on rather detailed field work.

On the other hand, a detailed survey of this county would require some time to complete. Using the British Land Utilisation Survey figure of two to three square miles per day, it is calculated that the survey would require about 160 working days in the field. The work would have to be spread over two field seasons because only the four months from June to September are suitable for land use observations in Quebec.

V. THE PURPOSE OF INTERMEDIATE METHODS

The Place of Intermediate Methods. The foregoing discussion indicates that the student of land use, in making his choice of method, will often find that both reconnaissance and detailed methods are unsuitable. A reconnaissance survey is preferable when a large area is to be covered, when the existing data is plentiful, or when time and expense must be considered. On the other hand, it may be felt that only detailed methods would furnish the amount of information required for an adequate analysis of land use. It is in such situations, where neither the reconnaissance method nor the detailed method is suitable, that the intermediate method finds its place.

Consequences of the Lack of Intermediate Methods. It is at this point that the land use surveyor faces a new problem: the choice lies among intermediate methods, but it is a scanty collection indeed from which one must be selected. So meager is it that often a suitable method cannot be found, and the surveyor, unwilling to use inadequate methods, is forced to reduce the area of his study until it fits within the practical limits of detailed survey.

An unfortunate consequence of the poverty of intermediate survey methodology is that it tends to result in scattered and piecemeal coverage of land use problems - - and scattered coverage provides neither the basis for a full understanding of broad regions, nor the information required for the development of land use planning policies. The Land Committee of the U.S. National Planning Board recognized the inadequacy of present methods, and in its report recommended the development of intermediate methods:

> . . . for rapidly classifying and mapping selected features of the land over wide areas. Something more accurate than reconnaissance is needed, but the method must secure coverage of large areas, in limited time intervals, and at low cost. (13)

VI. CONCLUSIONS

This chapter has indicated the need for intermediate methods, their place and purpose, and suggests some of the attributes which these methods must have:

> An intermediate method must provide a rapid rate of coverage, which in quantitative terms should be in excess of two square miles per day per survey team. This figure is based on the minimum coverage rate of the British Land Utilisation Survey.

> An intermediate method must provide results of

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(13) U.S. National Resources Planning Board, op. cit., p. 24.

greater precision than a reconnaissance survey. The degree to which this is accomplished may be assessed by comparing the distributional picture provided by the method with one provided by plotting statistical data.

An intermediate method should provide correlations of land use with physical conditions, without reliance on sources of information outside of the survey itself.

However, an ideal method is unlikely to be attained in practice because, as the previous discussion has indicated, intermediate methods are essentially a compromise between accuracy and expediency. The most successful method, in any given case, will be the one which achieves the best possible balance between two extremes.

Chapter III.

A COMPARATIVE REVIEW OF INTERMEDIATE METHODS

This study is naturally more concerned with sampling methods than with other intermediate systems of land use survey. However, a brief review of all types of intermediate methods is necessary because the hexagonal sampling system, if it is to be truly useful, must compare favourably not only with other sampling methods, but with intermediate methods of whatever type.

The general criteria upon which this comparison will be based have already been discussed in the preceding chapter. However, it now becomes necessary to examine some of these criteria in greater detail. Specifically, the nature of the results to be expected from a land use survey, as well as the methods and principles involved in obtaining such results, require further examination. To this end, the first section of this chapter is devoted to a discussion of the nature of land use phenomena and the need for objectivity in their study.

Intermediate methods are then classified into types, according to the principles upon which they are based, and representative examples of each type are examined with a view to evaluating their strong and weak points. Particular attention is paid to sampling methods, and an explanation is given of the difficulties which have so far discouraged a greater use of the sampling principle.

I. THE NATURE OF LAND USE PHENOMENA AND THE NEED FOR OBJECTIVITY IN THEIR STUDY.

Areal Relationships. Land use phenomena exhibit two-dimensional, areal relationships. For example, because of the nature of farm practices the use of a field for a certain crop is probably related to the use of adjacent fields. Similarly, a complex of land uses in one area is often explainable only in terms of the varying uses in nearby areas. On the other hand, the use of some lands may be restricted by the physical capabilities of the terrain, but they may be equally restricted by the capabilities of adjoining terrain. If a full understanding of land use is to be obtained, the survey method must be capable of bringing out these areal relationships.

Patterns. Land use phenomena form visible patterns, which differ from one area to another. The patterns are, of course, areal in nature, and the variations may occur because of physical factors, human factors, or both. For example, an area may exhibit a large-field pattern which may have been caused by the original subdivision of the area or by the physical qualities of the land. A thorough survey requires a method which will render these patterns, and their causes, apparent.

Boundaries. Boundaries between land uses will occur, some of which will be visible in the landscape, others indiscernible except through careful analysis of maps and statistical data. The boundaries may be sharp, or more in the nature of broad transition zones; they may coincide with changes in the physical characteristics of the land or follow economic influences such as marketing areas; they may be qualitative divisions between homogeneous complexes of land use, or they may represent small changes in one critical factor. An efficient method of land use survey will enable these boundaries to be determined with a high degree of precision.

Quantitative Aspects. Land use has quantitative as well as qualitative aspects. It is desirable to know not only the kinds of use within an area, but the intensity of each use, and the ratio of various uses to one another.. Similarly, the area covered by different terrain types and the percentage composition of the total surface must be considered. In addition, the quantitative relationships between land use and land type composition should be ascertainable. Methods of survey which do not permit the determination of these facts are of limited value.

The Need for Objectivity in Land Use Studies. All aspects of land use should be considered not only separately, but as a whole, if the study of land use is to be complete. The discerning analyst realizes that the apparent explanation of interlocking relationships may not be the true or only explanation. The hidden as well as the obvious must be sought, and analysis will be greatly assisted if the survey method is adapted to this task.

In this connection, the prime consideration is whether the proposed method is subjective or objective in character. A certain amount of subjectivity is unavoidable with any method, since an element of interpretation must be present even in the simplest of field observations, as, for instance, in deciding whether a particular field is a permanent or rotation pasture.

On the other hand, the method should make gross subjective judgments unnecessary, while methods which are simply a means of confirming preconceived concepts or explanations of land use should not be tolerated. Although this is a fairly obvious requirement, it is by no means universally accepted, in spite of such dicta as that of Hartshorne:

> Geography attempts to acquire knowledge of the world in which we live, both facts and relationships, which shall be as objective and accurate as possible.
> . . . .
> Likewise these ideals admit of no limitation in specific methods of observation in geography, but rather require that we utilize all methods that will lead to more accurate and certain knowledge. (1)

Summary. Besides providing the results outlined in the conclusions of Chapter II, intermediate methods should allow the study of all aspects of land use phenomena. Specifically, these methods should be capable of bringing out areal relationships, patterns, and boundaries, both qualitatively and quantitatively, and with the maximum possible objectivity.

With these criteria as a background, it is now possible to classify intermediate methods and to compare the advantages and disadvantages of the various types.

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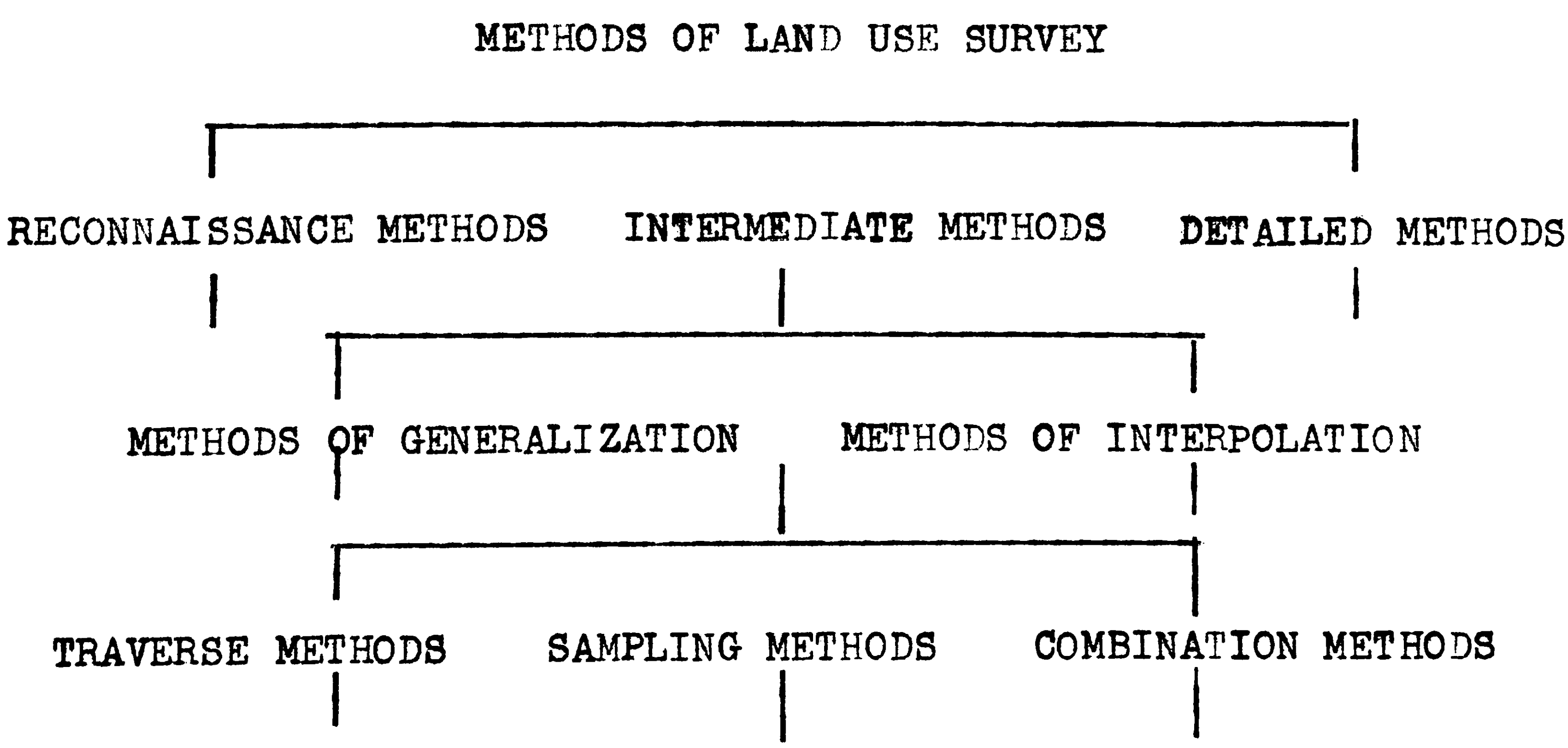
(1) Richard Hartshorne, The Nature of Geography. p. 375-6.

II. A CLASSIFICATION OF INTERMEDIATE METHODS.

Intermediate methods may be divided into the two primary categories, according to whether they are based upon the principle of generalization or that of interpolation. The former class depends upon identification in the field of homogeneous areas larger than the individual parcels of land, while the latter depends upon the interpolation of results from detailed studies over the total area.

Intermediate methods based on interpolation are of three kinds: those employing some system of traverses, those employing samples, and those combining traverses and samples. In all three types, detailed data collected for portions of the total area are used to interpolate land use conditions in those parts of the area which are not given detailed treatment.

This classification of intermediate methods, as it fits into the general framework of land use survey methodology, is indicated schematically below:



With traverse methods the detailed observations are made along lines or strips, while with sampling methods, detailed observations are made in discrete areas. Combination methods, of which the hexagonal sampling system is one, use some aspects of both traverses and samples.

Interpolative methods have been found useful not only in the study of land use, but in such fields as foresty and soil survey. The techniques used are quite analogous, and for that reason some examples of the use of interpolative methods in other fields are among those included in the following examples.

III. METHODS OF GENERALIZATION.

The Unit-Area Method. Perhaps the most familiar of all intermediate systems is the unit-area method. Based on the principle of generalization, it achieved prominence through its employment in the land-use mapping program of the Tennessee Valley Authority. The idea, however, was born some years earlier:

> . . . the idea of unit area classification carries back to a field conference in 1925. At that time I became hopeful that we might be able to perfect a technique by which one could recognize the entity of any point or area and then map that entity as far as it extended. (2)

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(2) C.C.Colby, cited by Jacks, op.cit., p. 7

Under this system, it is not individual fields or other small parcels that are mapped, but areas in which land use and physical conditions are fairly uniform. Depending upon the degree of generalization used, the rate of survey will be increased or decreased. This problem was carefully worked out in the Tennessee Valley, where the mapping was done using air-photo mosaics as base maps:

> Complete and balanced coverage was achieved in the unit-area survey by omitting no areas and by treating all areas with the same degree of detail. Rapidity of coverage was assured by making 200 acres the minimum-sized body of land, delimited by 'reading'' some landscape features directly from the aerial mosaics, and by providing for the use of cars.
>
> . . . .
>
> Each day's mapping begins with careful orientation. The landscape and mosaic are then studied to determine the character and extent of the first unit area to be mapped. A tentative characterization of the unit is made . . . Tentative boundaries are then drawn in yellow pencil, the limits of the unit depending upon the spread of relatively homogeneous conditions. Next the boundaries are checked and corrected at every point to which access is possible by roads, either immediately or when adjacent areas are being covered. During this process the landscape and tentative fraction [characterization] are scrutinized . . . . . Each succeeding unit area is similarly treated, a new unit being characterized and delimited if a change is noted in one or more of the items mapped. By this process, the pattern of enclosed unit areas and fractions is gradually completed. (3)

The entire upper Tennessee watershed was surveyed in this way, by teams of two whose rate of coverage was thirty-five to fifty-five square miles per day.(4) Characterization of each

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(3) U.S. National Resources Planning Board, op. cit., p. 119.

(4) G. Donald Hudson, "The Unit Area Method of Land Classification." Annals Assn. Am. Geog., 26:1936, p. 109

unit area was accomplished by the use of a fractional code, by means of which were recorded such items as agricultural emphasis, field size, farmstead quality, and the amount of erosion, degree of fertility, and stoniness of the soil.(5) A variety of maps on different scales were made from the field mosaics, while the land use data for each unit area were coded on Hollerith cards for statistical analysis.

Advantages and Disadvantages of the Unit Area System. The advantages of the method in providing complete, quick, and uniform coverage of large areas are such as to make it a very useful one in land use analysis. However, the method does have several disadvantages:

The quantitative extent of any particular land use cannot be determined from the results. Since the unit areas are generalized entities, the exact amount of each land use within that entity is known only in a qualitative way. This means that, except for maps of the generalized land use classifications which are the basis for characterization of each unit area, few quantitative distribution maps can be prepared.

The recognition of unit areas demands a high degree of competence on the part of the observer, for he must be able to detect, in the field, the uniformity within a complex of land

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(5) The complete fractional code used in the Tennessee Valley Survey is given in U.S. National Resources Planning Board, op.cit., p. 121.

uses. A certain amount of subjective judgment is unavoidable, due to the manner of observation and the nature of the classification system (which is itself a pre-determined and subjective interpretation of land use phenomena).

The method is mainly useful in areas characterized by sharp changes in land use and physical conditions. The Tennessee watershed, a mountainous and highly dissected region, was an area of this kind. But in areas of gentle relief having broad transition zones rather than sharp boundaries between land use complexes, the recognition of unit areas becomes difficult if not impossible.

Other methods based on the principle of generalization will have similar advantages and disadvantages to those found in the unit area system. The alternative is the use of a method based on the principle of interpolation; but the merits of these systems must be just as carefully assessed.

IV. METHODS OF INTERPOLATION: TRAVERSES

There are many possible ways of making a traverse study of an area. The traverses may be lines or strips; they may be laid out at random or in a variety of regular patterns, or they may be road traverses. Some of the possible systems of traversing an area are shown in Figure 1.

Pattern Traverse System. The original scheme of land use survey for the Tennessee Valley proposed a pattern traverse

Figure 1.

Some Ways of Traversing an Area.

A. Parallel Line Traverse. Measurements are made of the different land uses intersected by each line.

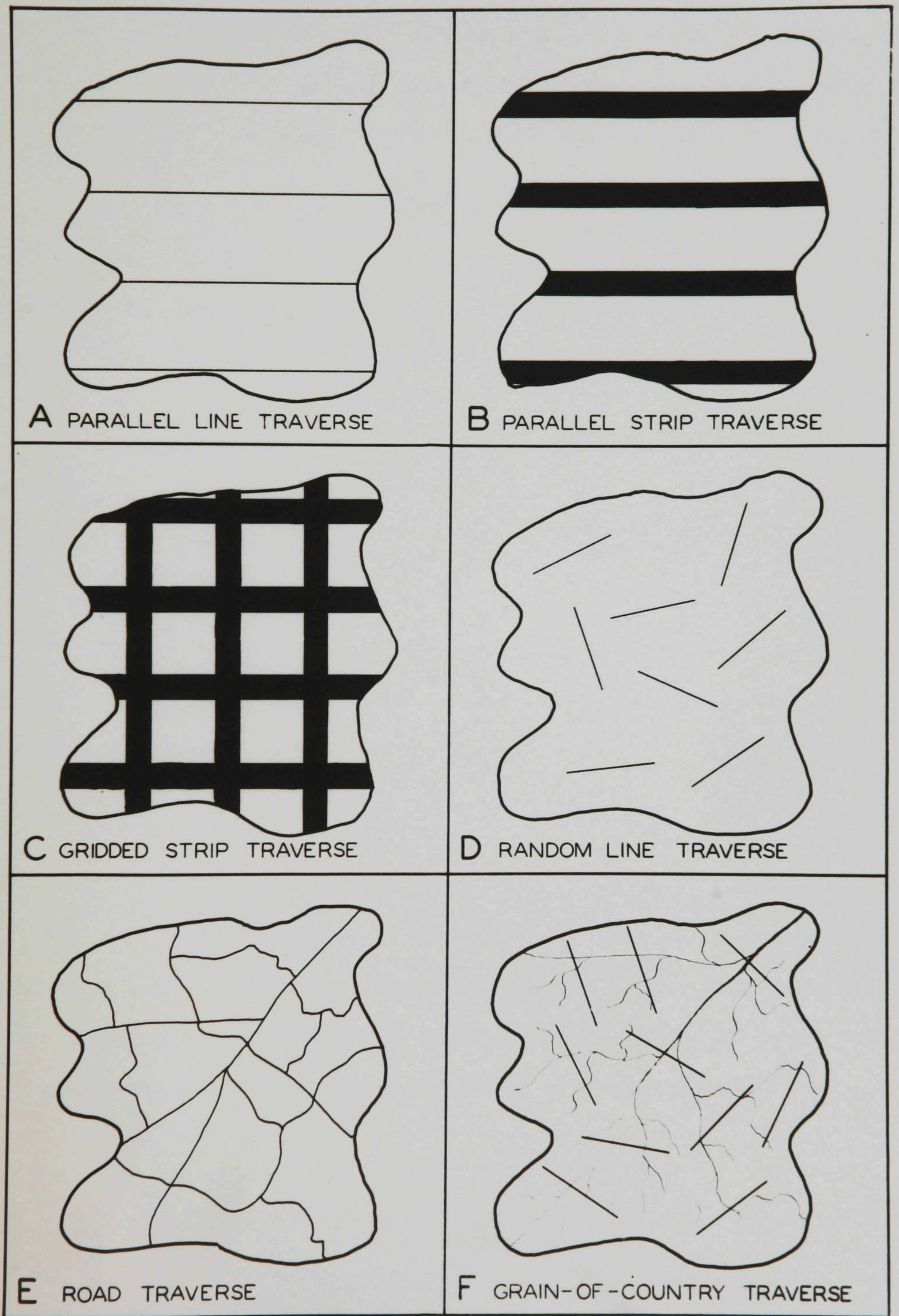
B. Parallel Strip Traverse. Each strip is mapped in detail.

C. Gridded Strip Traverse. Strips in two directions are mapped in detail.

D. Random Line Traverse. Lines of equal length are placed at random, and the different land uses intersected by each line are measured.

E. Road Traverse. Crop frontages along all roads in the area are measured.

F. Grain of Country Traverse. Traverse lines (or strips) are located at right angles to the stream pattern.


A PARALLEL LINE TRAVERSE
B PARALLEL STRIP TRAVERSE
C GRIDDED STRIP TRAVERSE
D RANDOM LINE TRAVERSE
E ROAD TRAVERSE
F GRAIN-OF-COUNTRY TRAVERSE

of the area. Strips four miles in width were to be surveyed in detail. These strips were to be laid out at right angles to the "grain" of the valley and at regular intervals. Additional traverses placed longitudinally were to complete the pattern.

Only one such strip was actually mapped before the scheme was abandoned in favour of the unit area system. It was found that traversing was taking too long, and the results were too detailed for the needs of the Authority.

Line Traverse. The Michigan Land Economic Survey carried out "soil and cover mapping" of the northern part of the state "on the general plan of running traverses through each section at intervals of one-half mile . . ."(6) The results were found to be more than adequate for the purposes of the survey, and it was possible to publish detailed soil and cover maps for each county covered.

Accuracy of Line Traverses. Valuable indications of the accuracy of line traverses are given by some experiments made in the Tennessee Valley. It was mentioned above that one strip traverse was mapped in detail in that area. Test traverse lines were drawn on this detailed map and the amount of each land use intercepted by these traverse lines was calculated. These amounts

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(6) U.S. National Resources Planning Board, op.cit., p. 104

were checked against the known amounts of land use for the area traversed, and it was found that "good results are obtained when the total length of the traverse lines exceeds one hundred times the average intercept of the field types traversed".(7)

Road Traverse. A road traverse system, in which the crop frontages along both sides of all roads in the survey area are measured, was developed by Hudson.(8) The area is divided into blocks each ten miles square, and the road traverse measurements for each block are used to draw isopleth maps of different land uses. No significant variations were found between the traverse figures and corresponding census figures; however, the traverses represent a very large sample, as it was estimated that over 90 percent of the total area was surveyed in this way.

Random Traverse. An ingenious random traverse system was used for a pasture study of Stanstead County, Quebec. Although the surveyors were interested in obtaining data on the distribution and quality of natural forage, the method offers some possibilities to the land-use surveyor.

> The impossibility of mapping a 400-square mile area . . . . made recourse to line transects, selected at random, essential . . . .
>
> Random selection was ensured in the following way. Starting at county boundaries in the case of main highways and at crossroads when using the secondary

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(7) Malcolm Proudfoot, "Sampling with Transverse Traverse Lines". Jour.Amer.Statistical Assn., 37: 1942, p. 270.

(8) G. Donald Hudson, "A Quantitative Approach to Land Use Problem". Annals Assn. Am. Geog., 25: 1935, p.44. Abstract only.

> routes, transects were run at right angles in every two miles from points on the roads chosen by random draw. Care was taken to avoid too close a grouping or intersecting of lines and the result was a reasonably well distributed sampling over the surveyed area. (9)

The accuracy of the method was checked by running extra transects in a portion of the area. These results compared favourably with those of the original transects, and also with figures for a part of the area that was completely mapped in detail.

Advantages and Disadvantages of Traverse Method. Traverse methods are particularly advantageous in determining the precise location of land use boundaries. This quality follows from the fact that the traverse lines or strips form a continuous network which cannot but intercept such boundaries as may be found within an area. The determination of boundaries will be especially good if the traverses make a criss-cross pattern; it may be less so if the traverses run in one direction only, if they are road traverses, or if they are widely spaced in relation to the spacing of boundaries.

Line traverses, however, will often be undesirable in that they cannot bring out the areal relationships between land uses. Strip traverses, it is true, do have this quality, but it is gained only at the expense of time-saving characteristics. For example, parallel strip traverses each one and one-half miles

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(9) C.Frankton and L.C.Raymond. "An Ecological and Crop Survey of Stanstead County". Sci. Agr. 22: 1941, p. 181

wide, at intervals of five miles, add up to a 30 percent detailed coverage of the total area. Gridded traversing on these same dimensions will bring detailed coverage up to almost double the above amount; this means that the survey will proceed only two to four times as quickly as a complete detailed survey.

In sum, traverse methods are advantageous in that they provide a network in which variations and transitions in land use may be caught. On the other hand, while they may be adapted so as to bring out spatial relationships, they are then likely to exceed the practical limits within which detailed survey may be carried out. As an alternative to traverses, sampling methods offer a rather different set of advantages and disadvantages.

V. METHODS OF INTERPOLATION: SAMPLING.

Samples may be used in as wide a variety of ways as traverses. The samples may be of uniform or varying size; they may be placed without reference to the varying characteristics of the area being surveyed, or they may be set within predetermined homogeneous regions. Figure 2 indicates some of the ways in which samples could be used to provide coverage for a land use study.

However, not all of these possible systems have been used. The success of sampling, like that of traverses, depends on the possibility of interpolating the results of the sample studies over the whole area. This problem has been largely

Figure 2.

Some Ways of Sampling an Area.

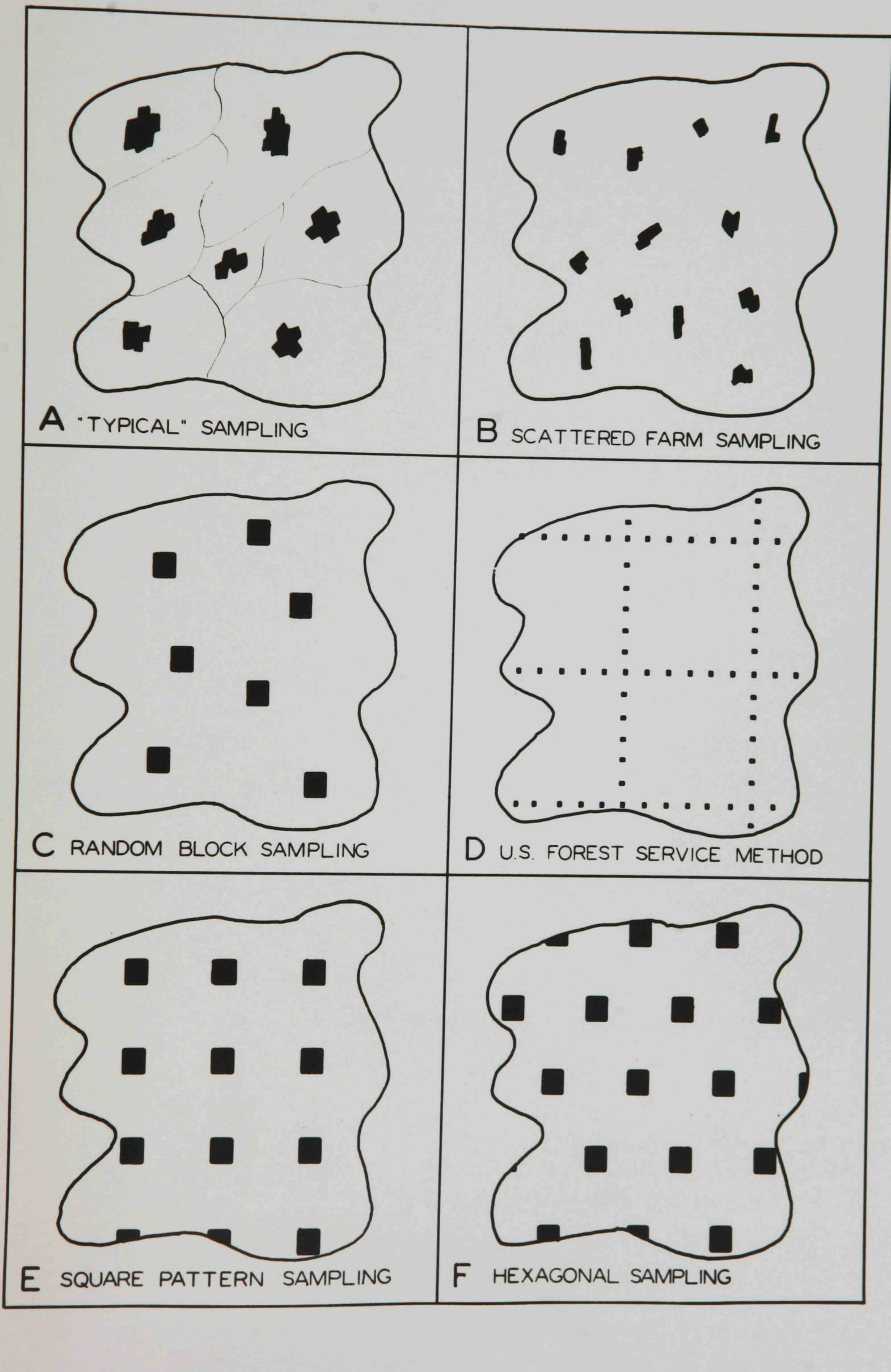
A. Type of farming or land use regions is determined, and a block of farms typical of each region is studied in detail.

B. Scattered farms are studied without prior determination of regions. This is a useful method when economic factors are to be taken into consideration.

C. Uniformly sized samples are placed at random. The distance between samples is not constant.

D. The U.S. Forest Service or "line plot" method for forest studies. Small sample plots are located at equal intervals along widely spaced traverse lines.

E., and F. Square pattern and hexagonal pattern sampling. Both are discussed in detail in Chapter IV.


A "TYPICAL" SAMPLING
B SCATTERED FARM SAMPLING
C RANDOM BLOCK SAMPLING
D U.S. FOREST SERVICE METHOD
E SQUARE PATTERN SAMPLING
F HEXAGONAL SAMPLING

neglected in the development of sampling methods for land use studies, and as the following examples will show, samples tend to be used in a rather elementary fashion.

"Typical" Samples. In geographic studies the use of "typical" samples is very common. A generally accepted view is that "sound generalizations about a region should be based on intensive studies of typical small areas".(10) This use of samples is well illustrated by a land use study in the Grand River Valley of Ontario.(11) Here the samples, each comprising a few farms, were so placed as to be typical of the farming regions within the area studied. However, these regions did not result from analysis of the sample data. The samples were used only to illustrate regions which had been determined by other means.

Quite a different use of typical samples is illustrated by Buck's study of land utilization in China.(12) Probably the most extensive of all land use surveys, it studied "16,786 farms in 168 localities, and 38,256 farm families, in twenty-two provinces in China".(13)

Although the surveyors "were instructed to make the farm

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(10) Wellington D. Jones, and Vernon C. Finch, "Detailed Field Mapping in the study of the Economic Geography of an Agricultural Area". Annals Assn. Am. Geog., 15: 1925, p.148.

(11) Chun-fen Lee, "Land Utilization in the Middle Grand River Valley of Western Ontario". Economic Geography, 20: 130-151, 1944.

(12) John Lossing Buck, Land Utilisation in China. 3 vols.

(13) Buck, op. cit., Vol II, Atlas, sub-title.

studies in localities which were typical of larger areas," the results of this work were used to typify and delineate regions over the whole of that portion of China studied.(14) Unfortunately, there is no specific statement of how this interpolation was accomplished, or of what checks on the accuracy of the system were employed. Apparently, the "larger areas" of which the farms studies were typical, were themselves assumed to be typical of still larger areas: Buck mentions that the usual unit of area for shading in the making of maps was the 'hsein' or county.(15)

The Use of Samples in Other Fields of Study. Although samples are used in several ways in many fields of study, no instance was found in which samples had been used for land use studie in any other way than that of the typical sample group, Generally students of land use are wary of these methods, for reasons which are not too clear. Colby states that interpolative methods "involve perplexing statistical questions,"(16) while Hudson remarks that " . . . the accuracy of the interpolated results is open to considerable doubt".(17)

On the other hand, botanists and biologists - - whose problems, after all, are not too unrelated to those of geographers .

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(14) Ibid., p. 7.

(15) Ibid., p. 46. Unfortunately, Volumes I and III of Buck's study were not available as possible sources of further information concerning the method employed.

(16) C.C.Colby, cited by Jacks, op.cit., p. 7

(17) G. Donald Hudson, "The Unit Area Method of Land Classification." Annals Assn. Am. Geog., 26:1936, p. 99

- have found interpolative methods neither perplexing nor of .oubtful accuracy. In fact, sampling forms the basis of most)f their areal investigations:

> Plant ecologists have devised numerous schemes for recording the species, density, and composition of vegetation. Most of them are careful methods of taking samples which may then be used as a basis for estimating the general condition of plant cover over an area which the samples represent. (18)

After describing the different kinds of samples, called uadrats in ecological terminology, Graham goes on to explain ιow the accuracy and adequacy of the method is checked:

> Attention should be given to the size of quadrat that can be expected to represent correctly the type of vegetation being sampled. How can one determine the smallest size of the individual quadrat and the smallest number of quadrats that will give a true picture of the plant cover? One way is to plot on graph paper the number of species (on the vertical axis) in a series of selected quadrats against the areas (on the horizontal axis) of the same quadrats and draw the resulting curve, called the species-area curve. The point at which the curve flattens out parallel to the horizontal axis determines the size of area sufficient to represent the flora being studied . . . . . The least number of quadrats can be determined in a similar way, by plotting number of species against number, instead of area, of quadrats. (19)

One might read "land use item" instead of "species" in ;he above citation, without in the least changing the logic of ;he method. There appears to be, then, no reason why land use studies should not make use of the obvious advantages which the principle of sampling affords.

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18) E.H. Graham, Natural Principles of Land Use, p.72

19) Ibid., p. 74.

<u>Advantages and Disadvantages of Sampling Methods</u>. As has been indicated above, sampling methods are relatively untried in the study of land use, except for those of the "typical sample" type. A properly designed method would, however, embrace many advantages not found in other intermediate systems:

The percentage of coverage can be reduced to a lower figure by the use of samples than with any other method; at the same time, this reduction can be accomplished without sacrificing the study of patterns, areal relationships, and quantitative data.

The main difficulty with the use of samples lies in the question of interpolation, especially with reference to the determination of boundaries. Since the samples do not form a continuous network, as do traverses, boundary lines can only be placed by indirect methods. Such a determination of boundaries is likely to be less accurate than a determination by direct observation, and it is this disadvantage which is the principal one to be overcome in the development of sampling methods.

VI. METHODS OF INTERPOLATION: COMBINATIONS

A logical step in the development of intermediate survey methods is the combination into one system of the advantages of both samples and traverses. Samples supply adequate areal data while giving a low percentage of coverage; traverses enable maximum accuracy in locating boundaries. Combination methods of this type are standard practise in forestry studies, but a search of the literature has revealed only one reference to the development of such a method in the field of land use.

Line-Plot Method. The U.S.Forest Service, in making a nation-wide forest survey, used a combination sample and traverse method for that portion of the country lying east of the Great Plains.

> Here, after careful checking for sufficiency and accuracy, the "line-plot" method which is being used in Finland and Sweden in comparable work was adopted. Under this scheme an area is gridironed by parallel compass lines 10 miles apart and extending as nearly at right angles to stream courses as possible. Sample plots, a quarter - to a fifth - acre in size, are taken at 10 chain intervals along these travel lines. On these plots detailed information is obtained and recorded, indicating whether the plot is farm or forest land; the kind, volume, and type of timber when present . . . and other pertinent facts bearing on forest production . . .. These plots are considered a representative sample of the entire area, and from them, total figures are computed. Relative accuracy of the information is computed by statistical methods and by comparison with more intensive cruises and cutting operations when these are available. Only generalized type maps are practicable under this plan. (20)

The brief summary cited above does not indicate how the traverses were used to supplement the plot data, but presumably they were helpful in the preparation of the maps.

The "Line-Block" Traverse. A technique similar to the line-plot method, but adapted to geographic surveying, is known as the "Line-Block" traverse. Although no details on the method other than those given below are available, the possibilities of the method for the study of land use are apparent.

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(20) U.S. National Resources Planning Board, op. cit., p. 55

> The "Line-Block" traverse is a combination of the usual traverse method of field mapping with small intensive, areal studies interspersed at regular intervals.
>
> The technique has a two-fold objective: (1) to gain a higher degree of accuracy in geographic field surveying than is possible through the use of the traverse alone, and (2) to achieve more rapid coverage than is possible when detailed mapping of a large area is attempted. It is felt that the method has sufficient flexibility to be applicable to a wide variety of geographic field studies. (21)

VII. SUMMARY AND CONCLUSIONS

The criteria for a successful intermediate method of survey must be based on the nature of land use phenomena, with its aspects of areal relationship, pattern, boundary, and quantitative measurement. The method must permit the simultaneous study of all these factors, while at the same time fulfilling the time - and expense-saving requirements as well as fulfilling requirements of accuracy and objectivity in the observation and measurement of land use.

Intermediate methods are based on either interpolation or generalization. Those of the latter type tend to be non-objective, and are thereby limited in the amount of quantative data that can be ascertained. However, they have definite advantages in providing complete and rapid coverage.

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(21) W.F.Christians, "The Line-Block Traverse". Abstract of a paper read during the December meeting of the American Geographical Society; Annals Assn. Am. Geog., 32: 1942, p. 108. It is unfortunate that only the abstract was published in the Annals, for correspondence with the author asking more information did not bring any reply.

Interpolative methods make use of either samples or traverses, or combinations of the two. Only traverse systems have been used to any extent for objective studies of land use, but good sample and combination methods have been developed in other fields of study. Traverse systems, when applied to land use, allow little areal interpretation of the data; if they are adapted to overcome this disadvantage, they tend to exceed the practical limitations of time and expense.

Sampling systems are generally of the non-objective, "typical sample" type. A search of the literature has revealed no method which has solved the difficulty of interpolating sample data. Since this problem has been effectively met in other fields of study, there seems to be no reason why the advantages of sampling should not be made of use in the field of land use.

The following chapters of this thesis describe, in the light of the above considerations, the development of the hexagonal sampling system as a possible solution of the problem of intermediate land use survey.

Chapter IV.

DESCRIPTION AND THEORY OF THE HEXAGONAL SAMPLING SYSTEM

A logical consideration of the essential requirements for a land use sampling device, which were discussed in the two preceding chapters, has led to the development of the hexagonal sampling system as it is presented in this thesis. In this chapter, the system as a whole is first briefly described, and then the theory of its separate aspects is discussed.

I. A DESCRIPTION OF THE SYSTEM AS A WHOLE

Essentially, the hexagonal sampling system consists of a number of sample blocks of equal size, uniformly spaced over the total area to be studied. The samples are spaced in an hexagonal pattern, as shown in Figure 2(F) and Figure 3.[1]

The size of the individual blocks and their spacing are kept constant for any particular area being studied. However, both size and spacing may be adjusted to the characteristics of the area, the degree of accuracy required, and the amount of detailed coverage permitted by practical limitations.

Land use is studied intensively in each sample block,

(1) A glossary of the special terms used in connection with the system, and describing its various elements, is given as Appendix A of this thesis,

and general observations are made along traverses between the samples. Within each sample, land uses and their accompanying physical basis may be mapped in as much detail as is required by the objectives of the survey. The traverse observations, which may be made either along lines or along roads, assist in the determination of boundaries and in gaining a broader picture of land use variation than is obtained from the detailed studies.

Quantitative results are obtained by measurement of the mapped land uses within each block. The accuracy of the total sample (all blocks taken together) can then be determined by comparison with whatever statistics are available for the whole area, and by determining how the results are affected when more or less samples are taken.

Once the accuracy of the results has been checked, the sample data may be used to interpolate land use conditions over the entire area. It is possible to draw both isopleth and dot maps to show the distribution of various uses, or the significant ratios of land uses to land types, by assuming that each sample is representative of a certain part of the total area. Isopleths or dots may be placed on the maps with or without reference to the distribution of land types; this depends on the character of the traverse observations and the amount of available information about soils, geology, and topography.

II. REASONS FOR THE USE OF THE HEXAGONAL PATTERN

The Advantages of a Grid of Equally Spaced Samples. The maximum objectivity in placing the samples can, perhaps, only be obtained by locating the samples completely at random and without reference to any feature of the study area except its broad outlines. However, it is felt that much the same result has been achieved by adopting a mechanical grid of equally spaced samples, and placing the grid itself in a random position on the area.

Theoretically, this method has practical advantages over completely random sampling, for with equally spaced samples the accuracy of the interpolated results is more nearly constant. Furthermore, a more uniform coverage of the total area is obtained, with no likelihood of any area being omitted through over-average. spacing.

The advantages of the Hexagonal Pattern over Other Possit Patterns. There are, of course, several different patterns that produce a network of equally spaced samples. Instead of the hexagonal pattern, it would be possible to use a square pattern or even a pattern of isoceles triangles. However, the hexagonal pattern is a refinement over the other possibilities from several points of view.(2)

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(2) The suggestion that a hexagonal pattern could profitably and advantageously be employed as the basis of a sampling system was originally made by Professor J.Ross Mackay, who, at the time this investigation began, had done considerable work on a related aspect of the hexagonal concept. See: J.Ross Mackay "Dotting the Dot Map". Surveying and Mapping, 9:1:3-10. 1949.

One reason for the use of the hexagonal pattern can be deduced from the nature of sampled areas. It is a basic assumption of this system that each sample is representative of a sampled area. The sampled area may be assumed to be circular in shape, with the sample at the center of the circle. When a number of these circular sampled areas are placed so as to cover an area ac completely as possible, their centers form a hexagonal pattern. This can be demonstrated by placing a number of pennies on a table-top, and packing them as closely together as possible: the centers of the coins form an hexagonal pattern. If the coins, or circular sampled areas, are arranged so as to form a square pattern, much more of the total surface remains uncovered than when the pattern is hexagonal.

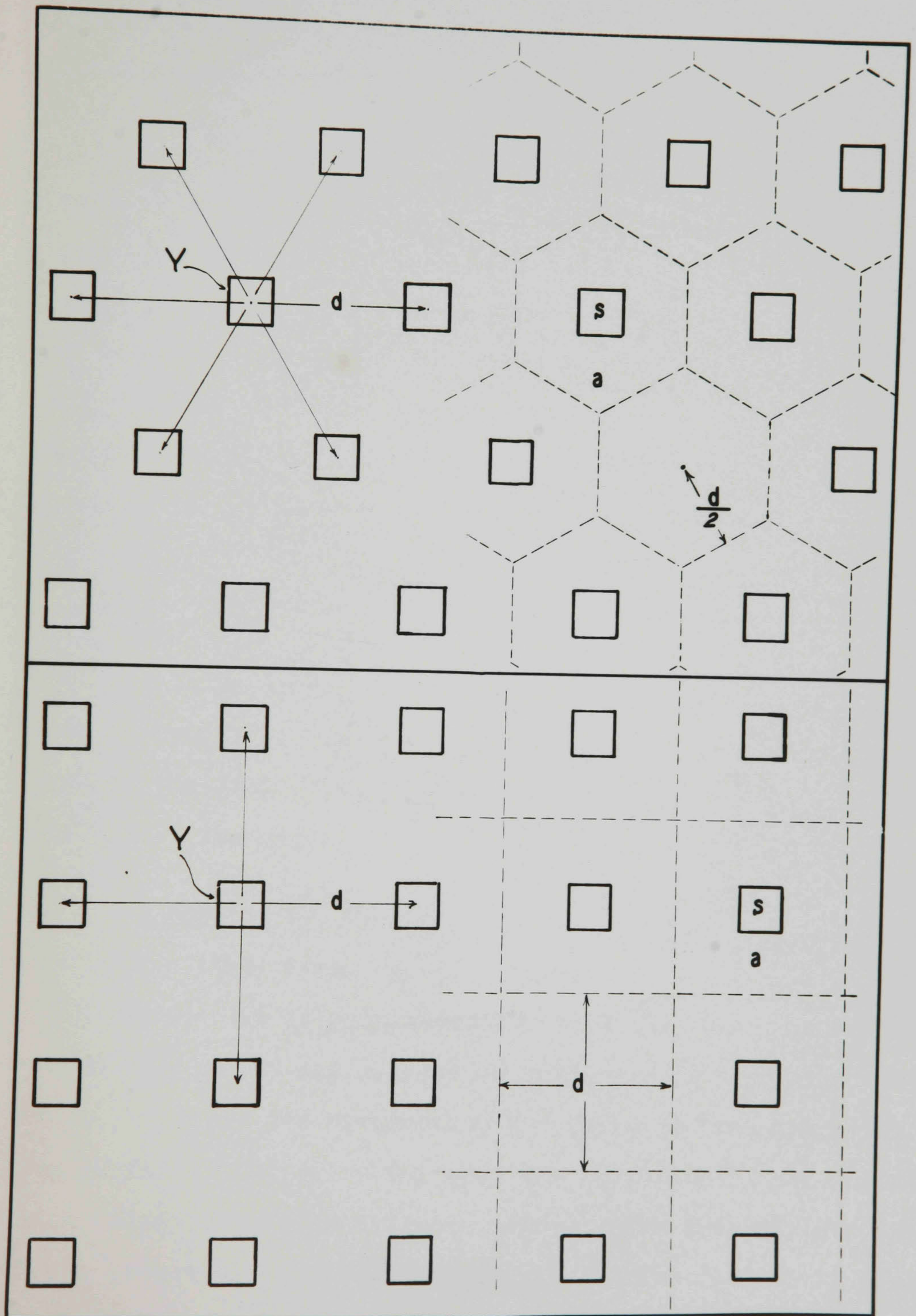
In addition, the hexagonal system is superior from the point of view of even spacing. Each of the patterns mentioned above has even spacing, it is true, but this concept needs a closer examination. Obviously, not every sample is equally spaced from every other sample; the relationship holds only for the smallest distance between samples. However, Figure 3 shows that in the hexagonal pattern, sample Y is equidistant from the six nearest samples, but in the square pattern, Y is equidistant from only the four nearest samples. This is an advantage for the hexagonal pattern because, for the same sample spacing, land use variations and boundaries are caught between a larger number of samples. To state this in another way, land use variations for the shortest distance between samples can be evaluated in six

Figure 3

The Dimensions of the Hexagonal Grid and the Square Grid.

The left side of each diagram shows the network of samples. Sample Y is an equal distance d from the six nearest samples in the case of the hexagonal grid, but is an equal distance d from only the four nearest samples in the square grid.

At the right side of the diagrams, the division of the total area into sampled areas is indicated. Each sample, of area s, is considered representative of a sampled area a. In the case of the square pattern, the sampled area is a square with length of side d, while in the case of the hexagonal pattern, the sampled area is a hexagon. Each hexagon consists of six equilateral triangles of $\frac{d}{2}$ and base $\frac{d}{\sqrt{3}}$



Y
d
s
a
d/2
Y
d
s
a
d

directions with the hexagonal pattern, but in only four directions with the square pattern.

<u>A Disadvantage of the Hexagonal Pattern.</u> There is one disadvantage to the hexagonal pattern: it requires the use of a greater number of samples than do other patterns, for the same spacing and total area. This point is more fully developed in the following section of this Chapter, but for the present it is sufficient to note that the hexagonal pattern is less economical than the square pattern, which is its closest rival in other respects.

III. THE DETERMINATION OF THE DIMENSIONS OF THE GRID.

In applying the hexagonal sampling system to any particular area, the first step is to determine the proper dimensions of the grid - sample size and spacing - and to adjust the grid to fit the area.

<u>Placing the Hexagonal Grid.</u> In placing the hexagonal grid on the study area, so as to determine the location of the sample blocks, it is only necessary to adjust the grid so that none of the blocks are located on urban centers or large water bodies, as these are areas which are negative from the point of view of rural land use. The grid may be placed in any position which fulfils these conditions; since there are many such positions, objectivity in the location of samples is readily possible.

However, dimensions of the grid are not arbitrary, but should be related both to the characteristics of the area concerned and to the practical limitations under which the surveyor must work.

Determining a Suitable Sample Spacing. It is desirable to have the sample blocks so spaced that in the final analysis, at least one sample will be provided for each area of differentiated land use. To state this in another way, the spacing between samples should not be greater than the average distance between land use boundaries.

Obviously, in an objective land use survey the boundaries will not be located until the office analysis stage, after the field study of samples has been completed. Nevertheless, it should be possible to estimate the average distance between land use boundaries in the preliminary stages of work through an inspection of topographic maps, a rapid field reconnaissance, and a consideration of available statistical material.

Determining a Suitable Size of Sample. The size of each sample block must also be related to the land use characteristics of the area concerned. Each sample should be large enough to show the land use patterns of its sampled area, and to give representative quantitative results. If an accurate sample of very minor uses is required, each individual sample will have to be comparatively large; if an accurate sample of only the major land uses is required, the samples may be smaller.

The most desirable way of determining the proper size of blocks would be to map one or two trial samples. The size of the blocks should be increased up to the point where any further increases do not cause any significant variations in the results obtained for the most minor use for which accuracy is desired.

A quick estimate of this optimum size can be obtained in another way. The basic unit of land use differentiation is the farm; hence, the sample should be at least as large as an average farm, and in order to allow for minor variations from farm to farm should be several times this size.

Furthermore, one dimension of the sample must be at least twice as great as the average longest dimension of a farm. The reason for this limitation can be seen more clearly from Figure 4, which shows a group of long-lot farms in Quebec. In this case, the rear portions of the farms are devoted to bush and rough pasture, while the cultivated portions are close to the road.

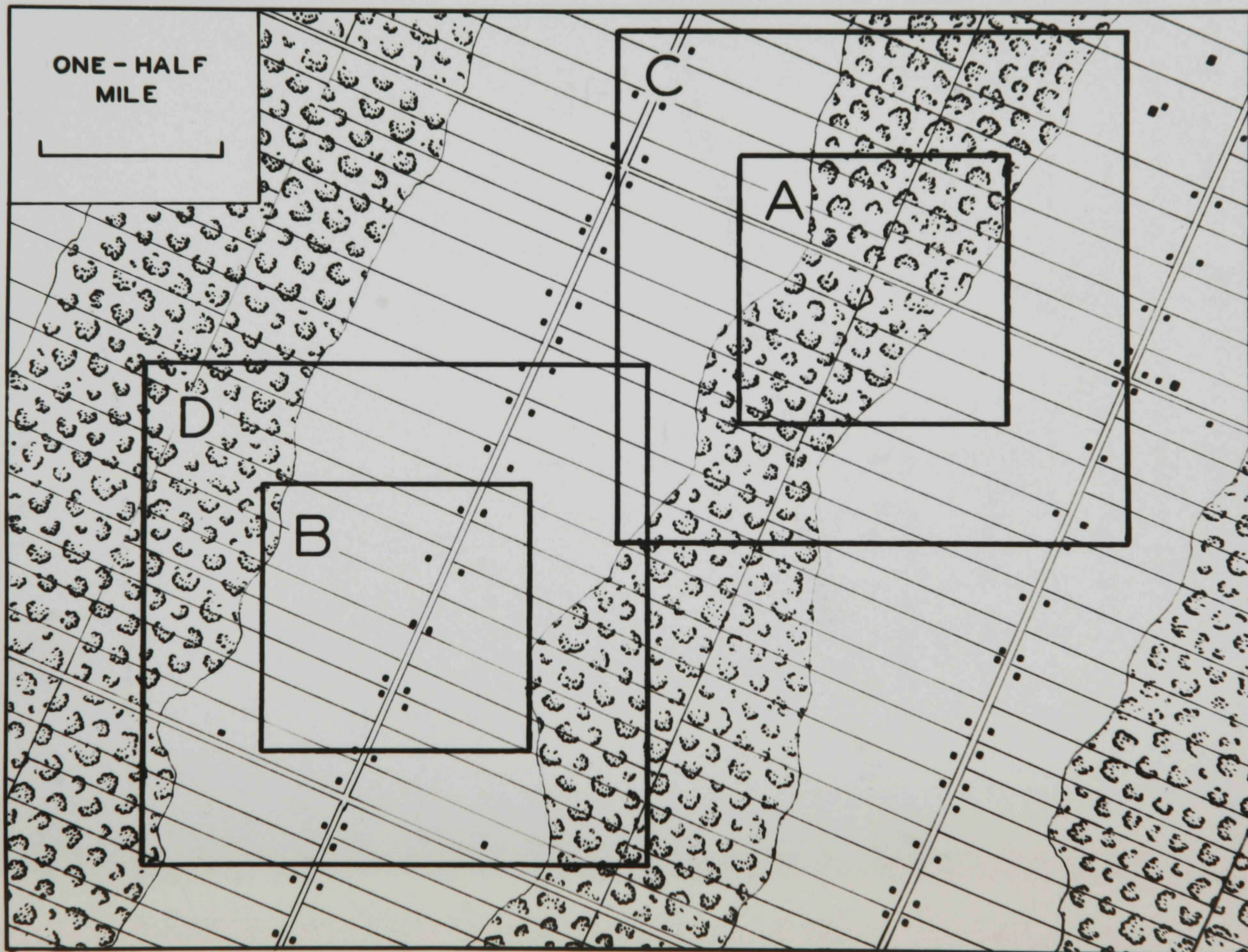
The two samples "A" and "B" have their longest dimension equal to the average length of farm, and as can be seen, very different results will be obtained from this pair of samples. Samples "C" and "D", on the other hand, have dimensions twice the length of farm, but will give rather uniform results in spite of the fact that they are in different positions.

Actually, the diagram shows an extreme case. On the average, land use conditions in a group of farms will be more homogeneous, so that a sample with dimensions of perhaps one-and-

Figure 4.

The Effects of the Random Location of Samples in an Area of Non-homogeneous Land Use.

The sides of samples A and B are equal to the average length of farm, while the sides of C and D are almost double this length. Sample A includes too high a proportion of forest and pasture to be representative of the area, while B includes too high a proportion of cultivated land. On the other hand, samples C and D are more nearly representative of the area, despite the difference in their location.


ONE-HALF
MILE
A
B
C
D

one-half times the length of the average farm will have a high probability of producing good results. This probability is increased because of the small chance that any one sample will be located at either of the most disadvantageous positions "A" or "B".

Determining the Percent Coverage.. Because of practical limitations, it will not always be possible to use the exact size and spacing of samples that theoretical considerations suggest. The land use surveyor will want to come as close to the ideal dimensions as possible, but these dimensions may make necessary a greater amount of detailed coverage than can be accomplished within the time and budget limits for any particular study.

In such cases, the surveyor must start with a given quantity -- the maximum allowable percent coverage -- and determine the combination of sample size and spacing that most closely approaches the ideal. Such a determination is most easily accomplished by means of the formulae set forth below, and the Percent Coverage graph shown in Figure 5.

When Samples are arranged in an hexagonal pattern (as shown in Figure 3) each sample may be regarded as being representative of a hexagonally shaped area, called the sampled area. As mentioned above (page 43), the sampled area may be regarded as being circular in shape, but it is necessary to assume an area of such a shape that no part of the total area is omitted: with the hexagonal pattern, the shape of the sampled area must therefore be hexagonal.

If the distance between centers of samples (sample spacing) is "d", the area "a" of the hexagonal sampled area is obtained by the following formula:

$$a = 6 \cdot \frac{1}{2} \cdot \frac{d}{2} \cdot \frac{d}{\sqrt{3}}$$

$$= \frac{6d^2}{4\sqrt{3}}$$

$$= 0.865d^2$$

The total area "A" equals the sum of all individual sampled areas, so that, if the number of samples is "n";

$$A = n.a$$

or

$$A = n.0.865d^2$$

Where the size of each individual sample is "s", the total sample "T" is the sum of all individual samples, so that:

$$T = n.s$$

The percent coverage "C" can then be expressed in terms of "s" and "d":

$$C = 100 \frac{T}{A}$$

Substituting, $C = 100 \frac{n.s}{n.0.865d^2}$

Simplifying, $C = 116.\frac{s}{d^2}$

These formulae may be compared with those for a square pattern, where each sampled area may be regarded as being a square with length of side equal to "d". Then:

$$a = d^2$$

And

$$A = n.a$$

$$= n.d^2$$

Or

$$n = \frac{A}{d^2}$$

Since the formula for the percent coverage remains the same,

$$C = 100 \frac{T}{A}$$

$$= 100 \frac{A}{d/2}$$

Curves for the percent coverage obtained with different grid dimensions in both hexagonal and square patterns are shown in Figure 5. By means of these curves, and the formulae, it is possible to determine suitable grid dimensions for any given percent coverage, or, for any given dimensions, the percent coverage necessary, In this way, the surveyor may balance his practical needs against the ideal dimensions suggested by theoretical considerations.

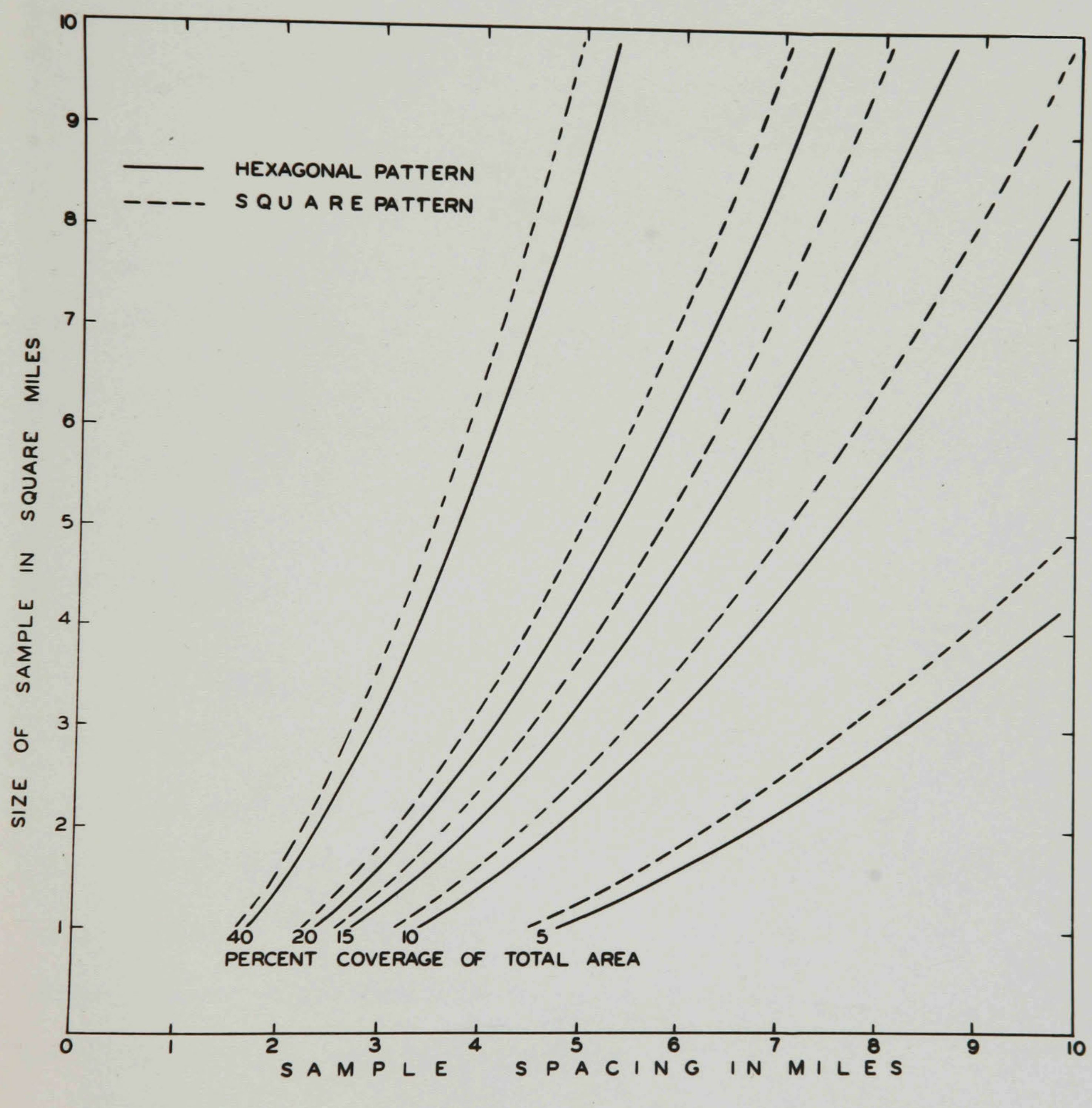
However, these formulae give only the minimum number of samples that will be required, for they do not take into consideration the complications introduced by an area with irregular boundaries, nor the fact that it may be necessary to have an additional number of samples around the periphery of the total area in order to permit interpolation right out to its borders. The discrepancy between the actual number of samples needed, and the calculated number, will increase as the size of the total area increases.

Figure 5.

Percent Coverage Curves for the Hexagonal Grid and the Square Grid.

The curves show the percent of detailed coverage required with any combination of sample spacing and sample size, irrespective of the size of the total area. Curves for 5, 10, 15, 20, and 40 percent coverage are shown, dotted for the square grid, and in solid lines for the hexagonal grid.

By reading sample spacing on the horizontal scale, and sample size on the vertical scale, the percent coverage required for any grid dimensions can be determined by interpolation between the percentage curves. The graph can also be used to determine what amount of detailed coverage would be saved by using the square pattern instead of the hexagonal pattern, or to determine the various grid dimensions that will produce any given percent coverage.


HEXAGONAL PATTERN
SQUARE PATTERN
SIZE OF SAMPLE IN SQUARE MILES
0
1
2
3
4
5
6
7
8
9
10
40
20
15
10
5
PERCENT COVERAGE OF TOTAL AREA
SAMPLE SPACING IN MILES

IV. TESTS OF THE ACCURACY OF THE TOTAL SAMPLE AND OF THE INTERPOLATION OF THE RESULTS.

As explained in section I of this chapter, the detailed studies of individual samples may be used to obtain quantitative land use figures. Before these results may be applied to land use analysis it is necessary to test their accuracy as a representative sample of the total area. Two kinds of tests of the accuracy of the total sample are possible: "independent tests" and "comparative tests". The first of these measures accuracy by statistical analysis of the sample data alone, while the second measures accuracy by comparing the sample data with data given by census returns. Both kinds of tests are explained in greater detail in Chapter VII, but for the sake of completeness a brief description is given here.

Independent Tests. The independent test involves the comparison of data from a portion of the total number of samples with data from the whole number. If, for example, the figures from every other sample are taken, the results obtained can be compared with the results given by all the samples. The degree of correspondence between the two figures is a measure of the accuracy of the original results.

As a variation of this test, additional samples may be mapped in portions of the area, and the resulting change in the figures for these portions noted. The size of this discrepancy is a further check on the validity of the original sampling.

Comparative Tests. The figures for different land uses obtained from the samples may be compared with available statistical data. The degree of correspondence obtained is a measure of the accuracy of the sampling over that portion of the area for which statistics are given. It may be necessary, however, to make some adjustments in cases where the statistical area and the studied area do not correspond, or where the land use categories of the sample study and statistical material are not precisely comparable.

The Range of Sampling Accuracy. From these tests a certain range of accuracy will be obtained. In general, accuracy will be greatest for those uses which occupy a large proportion of the total land surface, and accuracy will be least for those uses occupying the smallest proportion of the total. It follows that the map of any particular land use, drawn on the basis of the samples, will give a distributional picture that is precise to a degree directly proportional to the accuracy rating of that particular use.

The Accuracy of Maps Drawn by Interpolation of Sample Data. In drawing distribution maps of land use, it is assumed that each sample is representative of conditions in its sampled area, and that the variations of land use from one sample to another occur in a continuous manner. If, for example, a certain use is 20 percent of the total in one sample, and 30 percent in the adjoining one, it is assumed the point at which that use is 25 percent of the total occurs exactly mid-way between the two samples.

Under actual field conditions, however, such ideally continuous variation is rare, and abrupt changes in land use are likely to occur at distinct points of change in the physical conditions. Therefore, a more precise map is obtained if the map is drawn with reference to these physical conditions. In the final drawing of maps it is better to shift the isopleths in accordance with observations made along traverses.

The accuracy of these maps may be checked by measuring them, and comparing the results with the figures given by statistics. If, for example, the distribution map for a certain land use shows the areas where that use amounts to 10 to 20, 20 to 30, and 30 to 40 percent of the total, these areas can be measured and an average figure for the whole area computed. A comparison of this figure with the figure given by statistics is a measure of the accuracy of the map.

V. SUMMARY AND CONCLUSIONS.

The hexagonal sampling system is a device for the objective study of land use, designed to provide the maximum total coverage with a minimum amount of detailed survey, through the use of an hexagonal pattern of samples.

Theoretically, the system is flexible enough to permit of application to areas of widely different land use characteristics, yet the grid employed in any area is determined on the basis of its suitability to the area's characteristics.

Tests of the accuracy of sampling and interpolation are also provided in the body of theory on which the system rests. It remains to be seen in the following chapters how well this theory holds in its application to the study of land use within an actual area, a portion of the St. Lawrence Lowlands.

Chapter V.

A GENERAL DESCRIPTION OF THE HUNTINGDON CHATEAUGUAY AREA.

The Huntingdon-Chateauguay area was chosen for a test application of the hexagonal sampling system primarily because it offered a diversity of physical conditions with a wide variety of land use in an area of reasonable extent for which land use statistics were available.

The description given in this chapter is not intended to be other than a brief outline of the physical and human elements which make up the geography of the area. It is an introduction to the variegated landscape of Huntingdon-Chateauguay, included so as to familiarize the reader with the area and to point out the area's advantages as a testing ground for the hexagonal sampling system. Many of the points here briefly introduced will receive more detailed treatment in a later chapter.

I. THE LOCATION AND BOUNDARIES OF THE AREA.

Figure 6 shows the location of the Huntingdon-Chateauguay area within the general region of Montreal. The area comprises the two counties of Huntingdon and Chateauguay with the exception of a small Indian reservation at the extreme westerly end of the former county, and the two townships of St. Joachim and Ste.Philomène in the county of Chateauguay.

Figure 6.

The Location of the Test Area and Its Statistical Divisions.

The test area comprises most of the two counties of Huntingdon and Chateauguay. All numbered townships, except Nos. 1 and 2 in Chateauguay County, are included in the test area.

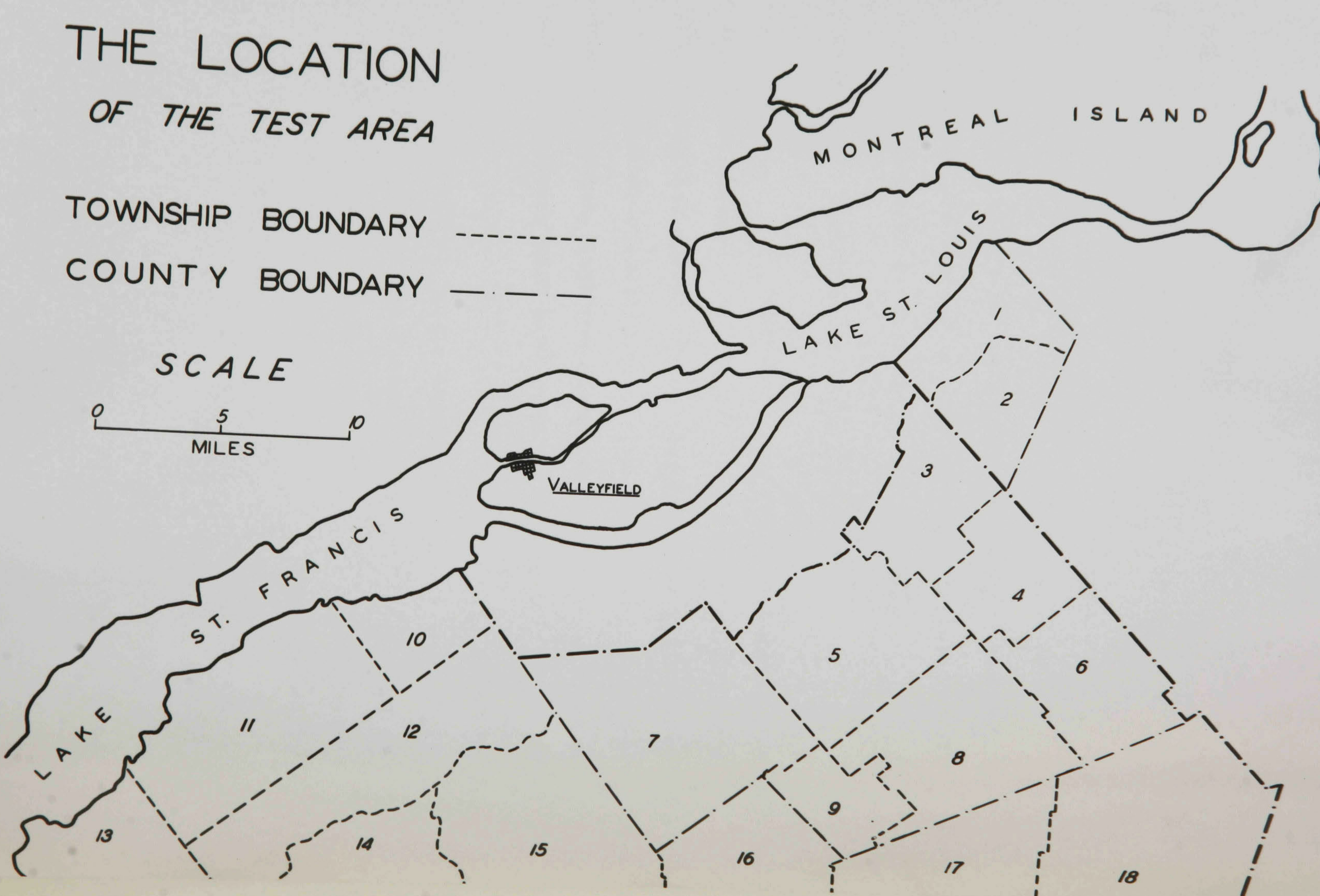
Index of Townships

Chageauguay County

1. St. Joachim de Chateauguay
2. St. Philomène
3. St.Paul de Chateauguay and Ste.Martine de Beauharnois
4. St.Urbain Premier
5. Très Saint Sacrement
6. St. Clothilde
7. St.Malachie d'Ormstown
8. St.Jean Chrysostôme de Russeltown
9. St.Antoine Abbé N.E.

Huntingdon County

10. Ste. Barbe
11. St. Anicet
12. Godmanchester
13. Dundee
14. Elgin
15. Hinchinbrook
16. Franklin
17. Havelock
18. Hemmingford


THE LOCATION
OF THE TEST AREA
TOWNSHIP BOUNDARY
COUNTY BOUNDARY
SCALE
0
5
10
MILES
MONTREAL ISLAND
LAKE ST. LOUIS
LAKE ST. FRANCIS
VALLEYFIELD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

These two townships were omitted because they form a long, isolated neck which could not readily be treated as an integral part of the main area studied.

The boundaries of the area, and the names and locations of the eighteen parishes into which it is divided, are shown in Figure 6. The total area, as measured by planimeter, is 580 square miles, and nearly all of this land is in farms: 339,700 acres, or 531 square miles, is the figure obtained from the census.

Although it would have been desirable to use a study area of a more rational shape and with "natural" boundaries, it was necessary to use political divisions in order to compare census data with sampling data. Census returns are published only for the areas enclosed by the otherwise meaningless boundaries between counties and townships.

II. THE PHYSICAL GEOGRAPHY OF THE AREA.

Geology.(1) The area is underlain by two principal rock formations, the Potsdam sandstones and the Beekmantown dolomites. They are distributed as shown in Figure 7. The

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(1) The most useful references on the physical geography of the area are:
J.A.Dresser and T.C.Denis, Geology of Quebec, Vol II, Descriptive Geology, 1944.
Annual Report of the Quebec Bureau of Mines for the Calendar Year 1930, Part D.
Ernst Antevs, Retreat of the Last Ice Sheet in Eastern Canada, 1925

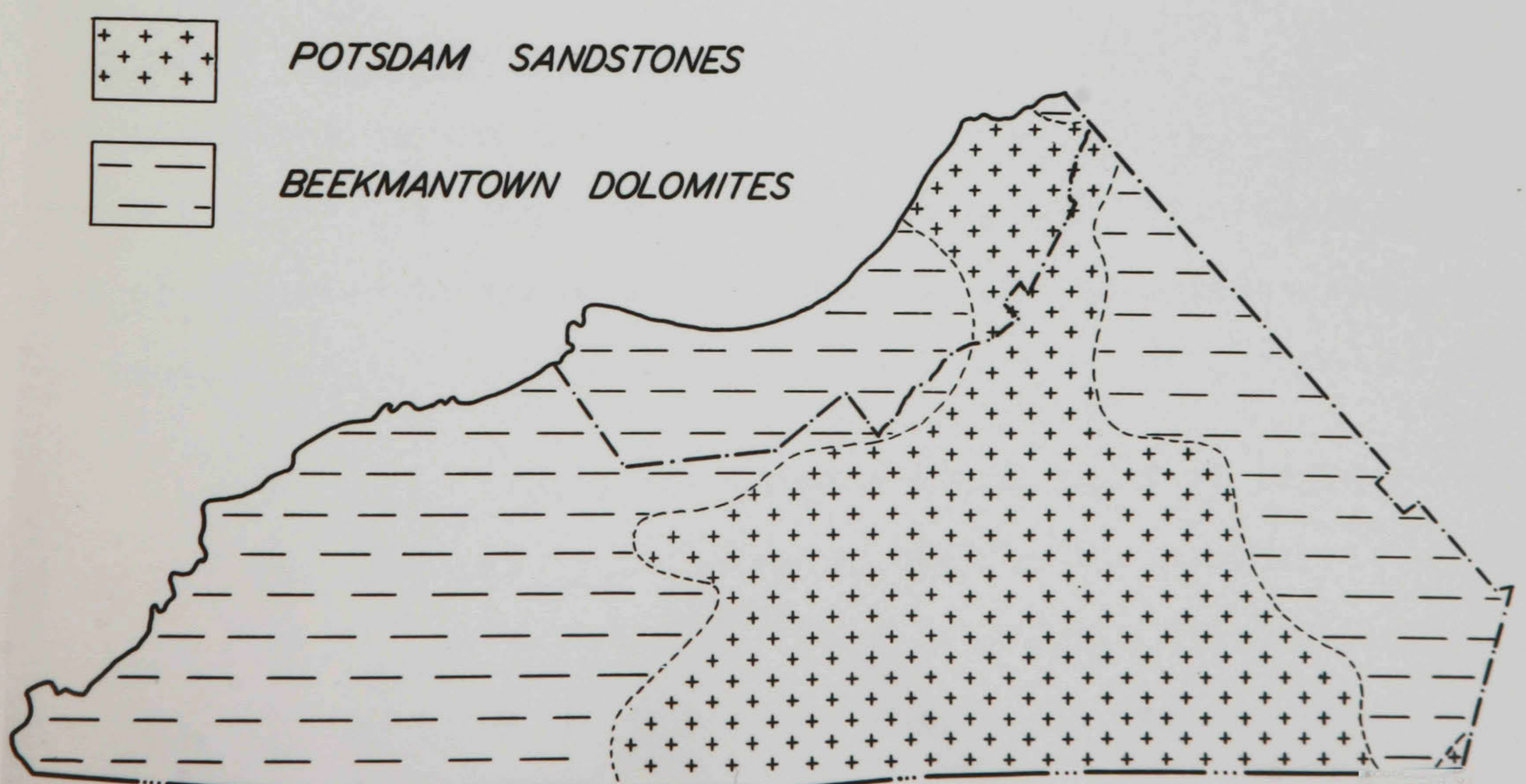
Figure 7.

The Surface Geology and the Elevations of the Test Area.

ELEVATIONS

CONTOUR INTERVAL 200 FEET

GEOLOGY



formations are the two earliest of the Palaeozoic series of flat-lying sedimentary rocks which underlie the entire St. Lawrence Lowlands. None of the later formations of this series occur in the test area because the Oka anticline, a very gentle upfolding, raised the sedimentary beds so that later peneplanation removed the upper layers of rock down to the Potsdam and Beekmantown..

The rocks are only slightly disturbed, showing nearly horizontal bedding in all their exposures, even on the rather steep slopes of the Adirondack massif in the southern part of the area.

The Potsdam sandstone is a hard, white, siliceous rock which is quite resistant to erosion; the Beekmantown dolomite, on the other hand, is a drab, rather soft, calciferous rock. Consequently, few exposures of dolomite occur, but exposures of sandstone are numerous and often many square miles in extent.

Glacial and Post-glacial History. The entire area was glaciated during the Pleistocene, and was later submerged under glacial lake Frontenac and the Champlain Sea. These two events imparted to the area the majority of its present surface characteristics.

The ice sheets deposited a thick layer of boulder clay over the old surface. This material was for the most part locally derived, so that the area may be roughly divided into two regions, in which the morainic material is derived largely from sandstone or from dolomite. A line dividing the two areas coincides generally with the geologic boundary shown in Figure 7.

During the period of submergence which followed the retreat of the ice sheet, sands, gravels, and clays were deposited in various parts of the area. These materials give rise, at the present time, to large clay plains and some sandy areas of smaller extent. While the sands and clays were being deposited the retreating waters also washed at the exposed parts of the ground moraine and at the slopes of the Adirondacks, so that both areas now have the appearance of abandoned beaches.

As the land gradually rose and the waters of the Champlain Sea retreated, conditions of poor drainage and shallow water became prevalent over large parts of the area. Peat bogs formed in these places, and some of the bogs still remain, while of others all that can be seen is the organic soil of the degenerated peat.(2)

<u>Drainage</u>. At the present time, nearly the entire area is drained by the Chateauguay River and its principal tributaries the Trout, Black, and English rivers. Some slopes on the western side drain directly into the St. Lawrence through a number of creeks. Figure 8 shows the principal stream pattern of the area.

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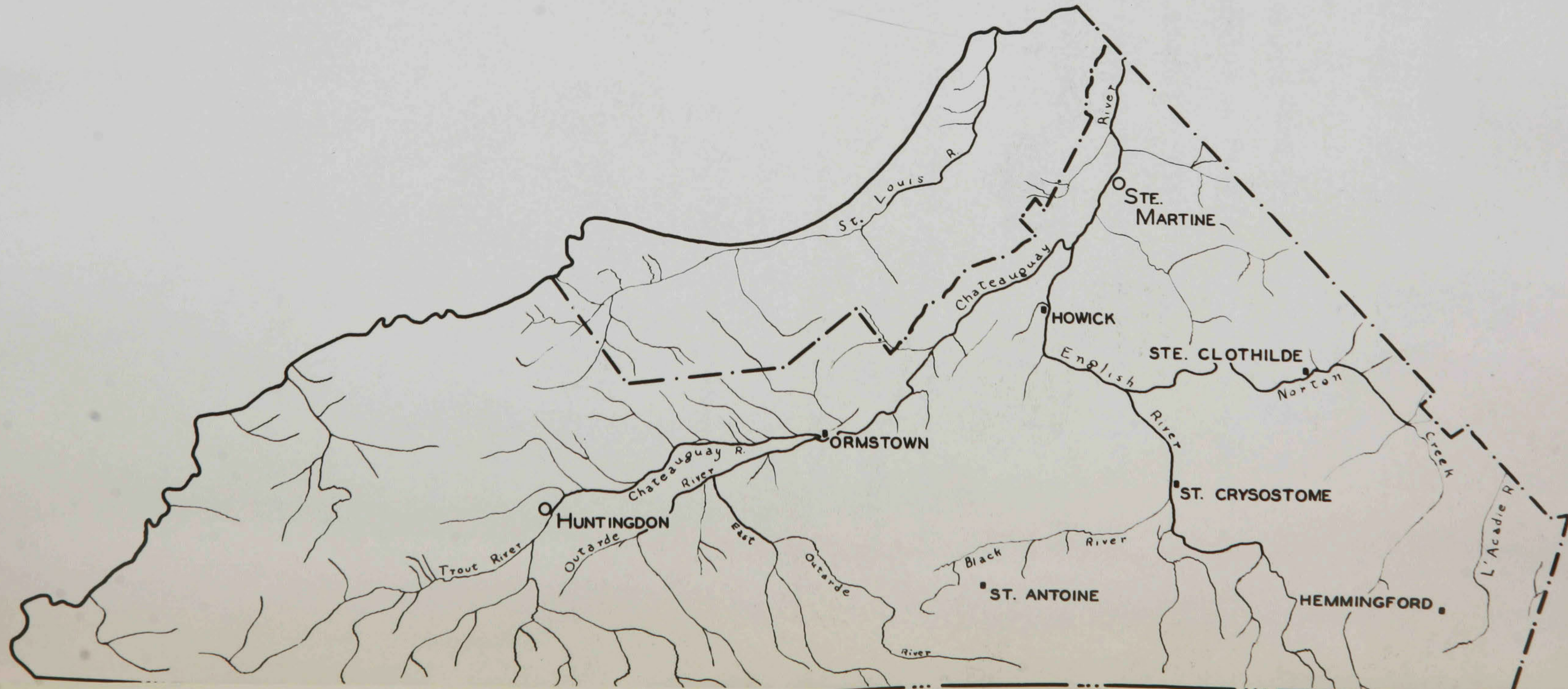
(2) The bogs of this area have been studied by V. Auer, <u>Peat Bogs in Southeastern Canada</u>, Geological Survey Memoir No. 162, 1930.

Figure 8.

The Drainage Pattern and the Principal Towns of the Test Area.

HYDROGRAPHY

AND PRINCIPAL TOWNS



The old topography of the area was completely obliterated by the deposits of glacial and post-glacial times. On the new surface, a new drainage pattern was established, and the pattern still shows signs of poor integration. Many falls and rapids occur where the rivers have encountered bedrock after cutting rapidly down through the soft surface layers, and the continued existence of areas of swamp and poor subsoil drainage indicates that the stream pattern has not reached full development.

Physiography. In standard physiographic references, the Huntingdon-Chateauguay area is usually included as part of the St. Lawrence Lowlands.(3) The term "lowlands", however, is hardly descriptive of some parts of the area. The northern slopes of the Adirondacks project for about three miles across the southern boundary of the region, and the land rises from three hundred feet to over 1100 feet within that distance.

Elevations over the greater part of the area are from 125 to 250 feet above sea level; but the region, although it may justly be described as a lowland, certainly does not have the appearance of a plain. Except for the flat areas of clay soils which are especially dominant in the Chateauguay valley proper, the country is a complex pattern of low, bouldery,

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(3) See: Wallace W. Atwood, The Physiographic Provinces of North America, p. 173, and accompanying map by Erwin Raisz; A.K. Lobeck, A Physiographic Diagram of North America; and N. Fenneman, Physiography of Eastern United States, p. 397 and Plate I.

morainic ridges from 25 to 75 feet in height, with narrow intervening vales of level clay or muck land. In some places this pattern is broken by bogs, rock outcrops, or undulating sandy plains, while the ridges themselves are by no means constant in size and extent.

The occurrence of clay plains and ridge lands is related to elevation, with the clay concentrated below 200 feet and the ridges dominant at higher elevations. The first beaches and terraces of the Adirondack slopes are found at about 300 feet. This general division may be grasped by a glance at Figure 7, showing the contours of the area.

Soils and Natural Vegetation. The soils and natural vegetation types of the area exhibit a striking diversity. The latest studies indicate that the area is in a "zone of tension" between the gray-brown podzolic and brown forest soils.[4] Further complications are introduced by the varied nature of the materials upon which the soils have been developed, and by drainage conditions.

Besides the soils of the two groups mentioned, there are large areas of intrazonal and azonal soils: bogs, half-bogs, sandy podsols, lithosols, and undifferentiated recent alluvium. However, as far as land use in this area is concerned, it is the differences in soil textures, drainage, and ease of cultivation

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(4) Roger Baril, "Etudes Pédologiques des Sols du Québec," Agriculture, 5: 1948, p.18, and map p. 15.

which are important. These factors are considered in more detail in Chapter IX.

Natural vegetation in the area falls into four classes from the land use point of view: climax vegetation; retrograde climax vegetation resulting from man's interference; vegetation renewing its succession towards the climax as a result of release from man's interference; and specialized quasi-climax vegetation due to atypical climatic or edaphic factors.

The climax forest vegetation which develops in this area in response to its climatic and soil conditions is the Aceretum saccharophori laurentianum, or maple-beech association, in which the dominant is the sugar maple tree with lesser numbers of beech and white ash as co-dominants.[5] However, because the effects of man's interference are widespread, few examples of the climax in perfect condition are to be found.

Associations representing one or the other of the early stages in succession towards the climax are characteristic of the area. Of these, the white cedar association (an almost pure stand of thuja occidentalis), and the silver maple - white elm sub-climax are the most prevalent.[6]

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(5) Pierre Dansereau, "L'Erablière Laurentienne. II. Les Successions et Leurs Indicateurs". Canadian Jour. Research, Series C, 24: 1946, p. 268.

(6) Ibid, p. 256 f.

Most of the maple forests have suffered a retrogression to a disclimax, in which the effects of man's interference by clearing, tapping, or pasturing are marked. There are also areas in which the lessening of man's activities allowed a renewed succession towards the climax to begin. Some under-pastured areas, for instance, are invaded by the hawthorn wire-birch association,(7) indicating that man may be gradually abandoning the area.

Quasi-climax vegetation is produced in areas of specialized environment, as, for instance, the paper birch - balsam fir association of bog and frost pocket areas,(8) or the wire birch stands of areas with dry and shallow soils.(9)

III. THE PATTERN OF HUMAN OCCUPANCE.

Upon the pattern of rocks, soils, landforms, and forest types, there has been imposed an equally complex pattern of human occupance. Land use in the area derives its characteristics from the relationships which have been developed between human activities on the one hand and the physical elements on the other.

History and Settlement. The area was subdivided into long-lot farms and fully settled over a century ago. The

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(7) Ibid, p. 258.
(8) Ibid, p. 256.
(9) Ibid, p. 261.

French came earliest to the most northerly parts, but the southern section remained uninhabited for many years because of its close proximity to the then-unfriendly United States. Not until after the War of 1812 did colonization really get under way, when large numbers of English and Scotch settlers entered the area and took up the remaining lands.

Population increased until about the end of the 19th Century, when a decline set in. The British in particular began to emigrate, and their places were taken by the French; not, however, in sufficient numbers to fully offset the decline which continues to the present day.

The Rural Character of the Area. The orientation of the area is distinctly rural, with very little industry occurring even in the major towns of Huntingdon and Ste.Martine. These two are mainly market towns, with some light industrial plants for processing rural produce. The smaller towns and villages, of which the most important are Howick, Ormstown, Hemmingford, St. Urbain, and Ste. Clothilde, are definitely local markets each servicing and supplying its own rural district. The locationsof the principal towns are shown in Figure 8.

The Types of Rural Activity. Dairy farming is almost everywhere the keynote of rural activity, as it is in all parts of the Montreal region. There are, however, many important subclasses to this type of farming, most of which take the form of dairying in combination with some other specialized activity.

The most widespread of these are the breeding of purebred cattle, poultry raising, apple growing, and the growing of vegetables for commercial canneries. Each of these kinds of farming has its own area of dominance, sometimes in response to the physical environment, sometimes in response to purely economic conditions.

The Variety of Land Use. As types of farming differ, so does intensity of land use. In some sections less than fifty percent of the land is classified as "improved", while in others may be found some farms which are fully improved. In similar fashion the way in which arable land is distributed among the key crops differs from area to area. Hay, for instance, averages over 70 percent of all field crops along the slopes of the Adirondacks, but it is less than thirty percent in the vegetable-growing region of Ste. Martine. The maps of population and land use, Figures 9 to 11, which were drawn on the basis of 1941 census returns, show the contrasts of the test area quite clearly, but nevertheless in a very generalized fashion.

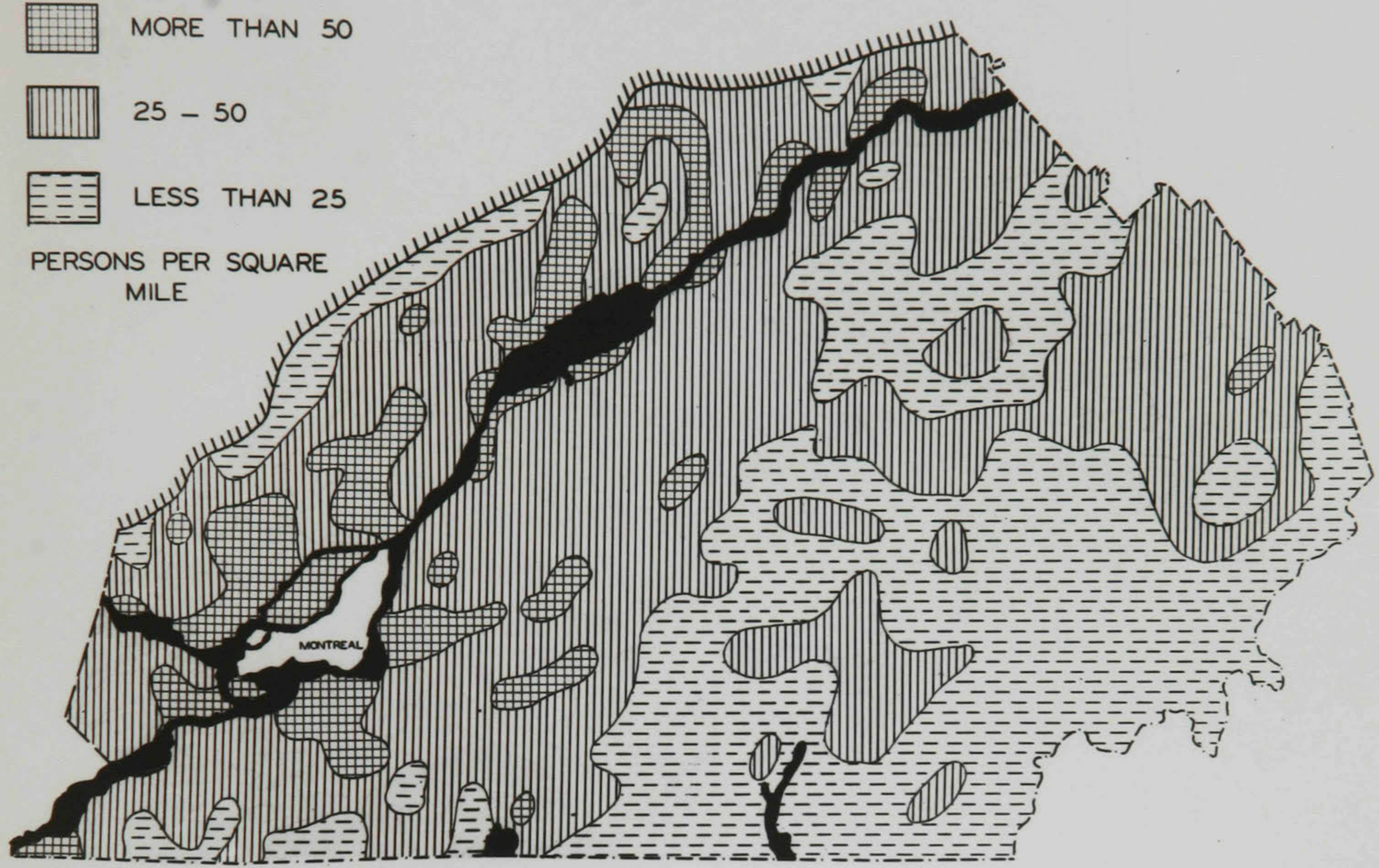
IV. THE ADVANTAGES OF THE AREA AS A TESTING-GROUND FOR THE METHOD.

Few places in the province of Quebec provide such an abundance of contrasts among both physical and land use factors as the Huntingdon-Chateauguay area. These contrasts provide an unequalled opportunity for the full testing of the hexagonal sampling system.

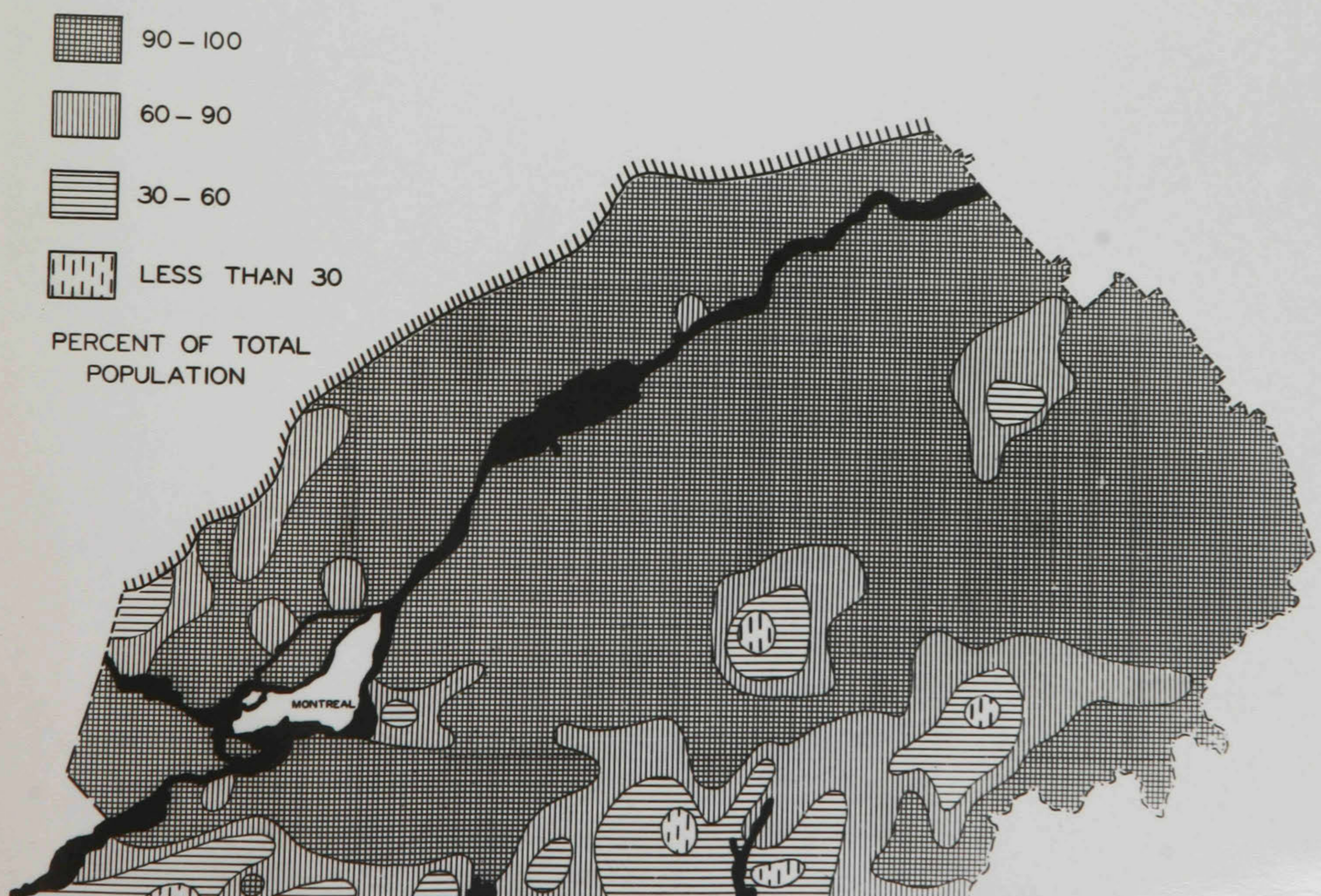
In some parts of the area, land use boundaries are

Figure 9.

Statistical Maps of Rural Population Density
and
Ethnic Composition in Southwestern Quebec.



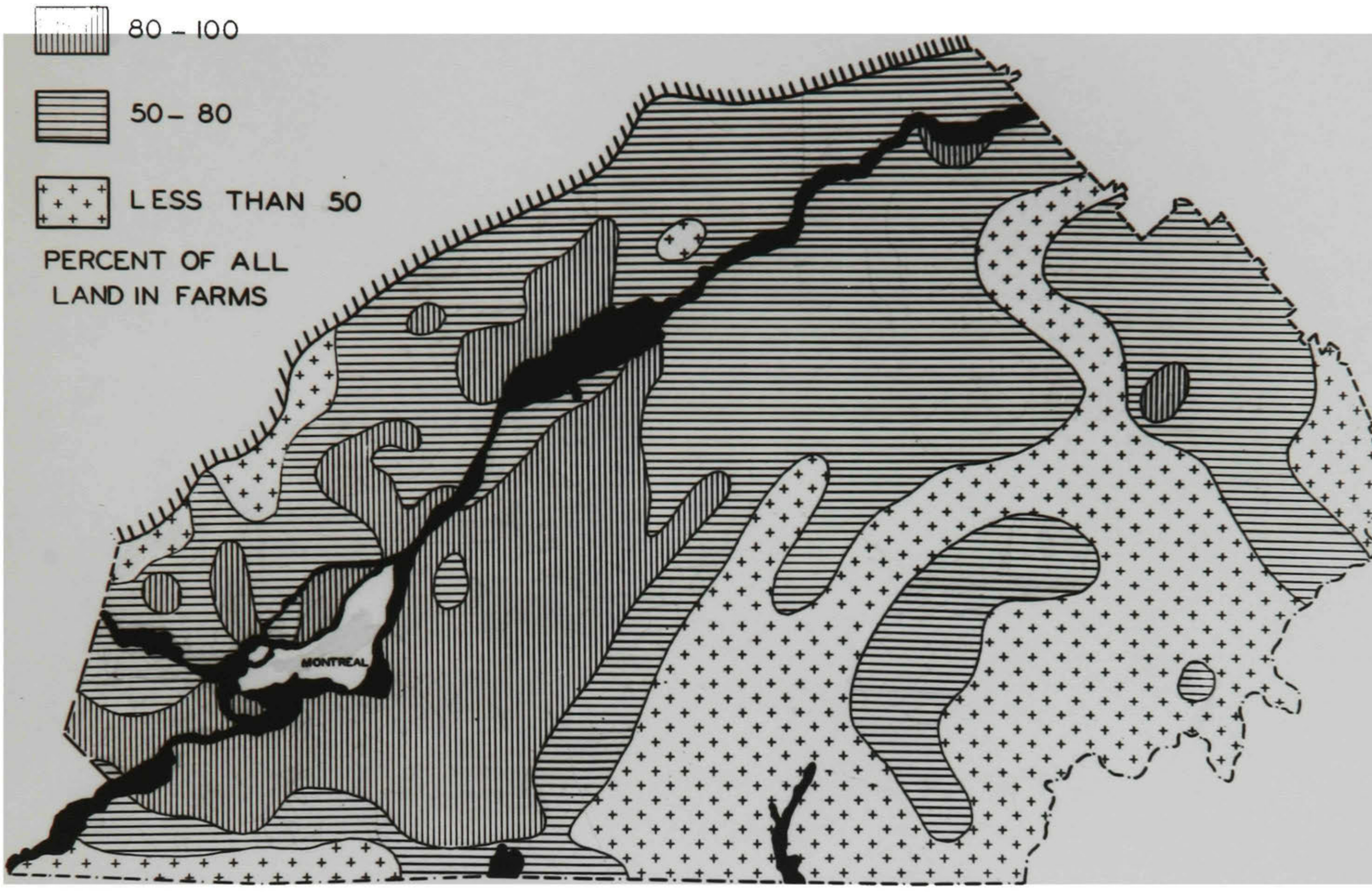
RURAL POPULATION DENSITY



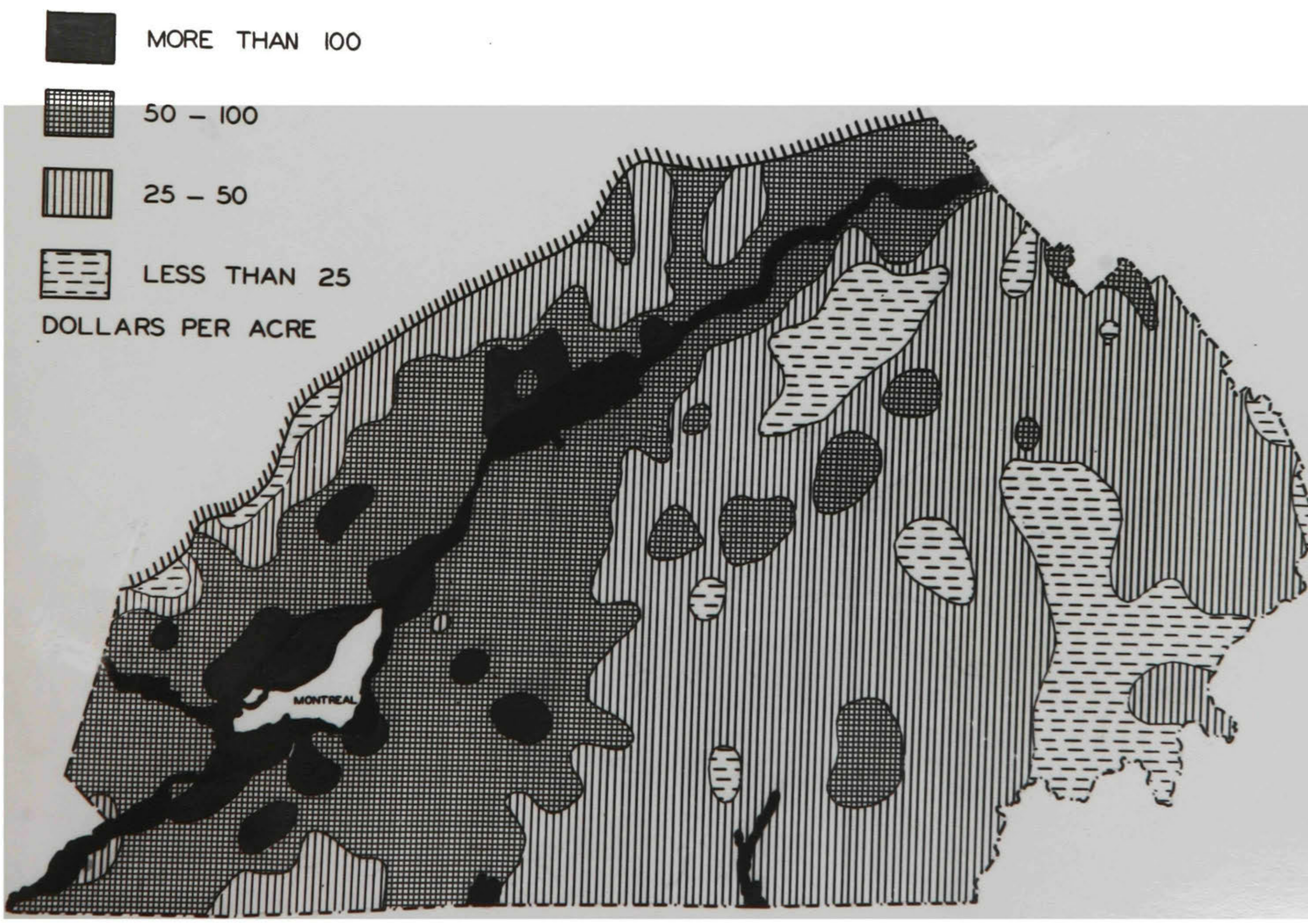
FRENCH RURAL POPULATION

Figure 10.

Statistical Maps of Percentage of Improved Farm Lands and the Farm Values in Southwestern Quebec.



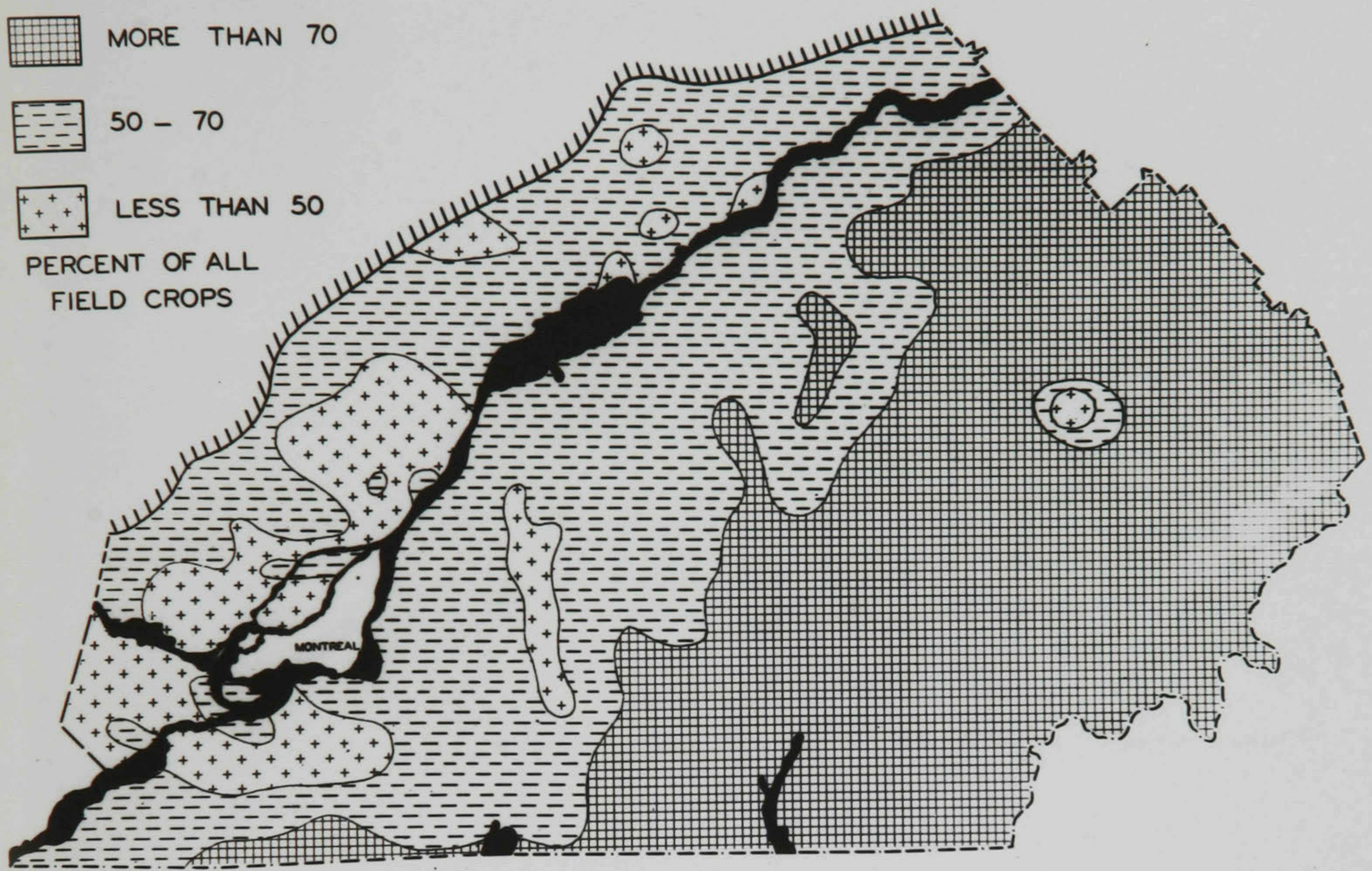
IMPROVED LAND



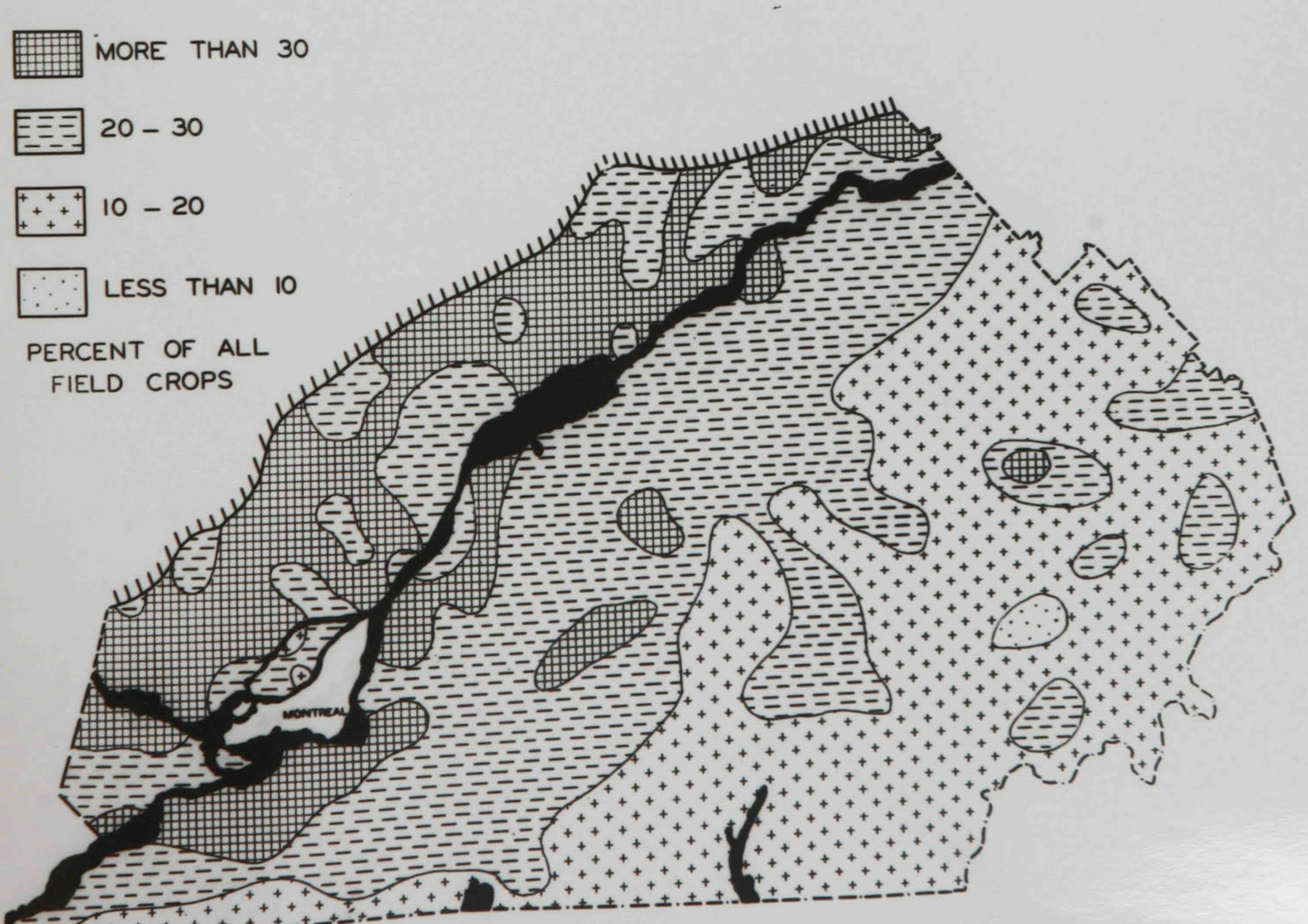
FARM VALUES

Figure 11.

Statistical Maps of Hay and Oats as a Percentage of Field Crops, in Southwestern Quebec.



HAY ACREAGE



OATS ACREAGE

close together, in others far apart. In some parts, land use responds more closely to variations in human factors than to physical ones. A variety of patterns occurs, as well as a variety of farming types and living standards, density of settlement, and makeup of population. Thus the hexagonal sampling system can be tested against a whole series of different land use problems.

Notwithstanding all this desirable contrast, the area was sufficiently small to permit field work to be completed within one field season. In addition, the area proved to be one of the few for which all of the necessary pre-survey materials and information were available; particularly soil surveys, and vertical aerial photographs for use as large-scale base maps in the detailed sample studies.

In the following chapter, a report is given of the manner in which the hexagonal grid was applied to the area, and of the way in which field studies were carried out.

Chapter VI.

HEXAGONAL SAMPLING IN THE TEST AREA

This chapter, which presents details of the application of the hexagonal sampling system to the Huntingdon-Chateauguay area, is divided into two sections. The first concerns the manner in which the size and spacing of samples were adjusted to the area, the final location of the samples, and other preliminary details. In the second part, a report of the field work itself is given.

I. APPLICATION OF THE HEXAGONAL GRID

The decision to use the Huntingdon-Chateauguay area for a test of the sampling system was made in April 1948. Early in the following month, a day's preliminary reconnaissance provided some first-hand acquaintance with the area. In the interval, all the available data covering the area was assembled, including geologic and soil-survey reports and maps, topographic, cadastral, and statistical maps.

<u>The Choice of Grid Dimensions.</u> The next step was to determine the dimensions of the grid. A number of different grids, using a varying combination of sample sizes and spacings, were constructed on transparent overlays. These sheets were then placed on the topographic maps, and, having regard to available data and first-hand observations, a choice was made of the grid that

It was felt that, on the average, a grid using samples of two square miles, with five miles distance between centers (approximately 3.5 miles between edges) would be most effective in sampling each type of land use and in catching the boundaries between uses. At the same time, this grid provided a percent coverage of only 10 percent.

Although the choice of sample size was not made on the basis of the theory presented in Chapter IV, it is nevertheless felt that the choice was a reasonable one. Since the objective of this survey was to test the method, it was not a requirement that accuracy be attained in the sampling of any one category of land use, or any one particular crop. The requirement was, rather, that an accuracy range indicative of the method's possibilities be obtained. Such a range is most conveniently expressed in round-figure terms. Consequently, the two square mile value was adopted as the one which most closely approximated a sample having dimensions twice the average length of farm.

<u>Location of Samples.</u> The dimensions of the grid having been determined, the next step was to locate the samples. The transparent overlay, on which the grid was drawn, was placed on the topographic map and adjusted so that no sample included parts of any large water body or urban settlement. The resulting sampled areas are shown in Figure 12.

It was then necessary to secure the vertial air photographs which were to serve as base maps. Topographic sheets, upon

Figure 12.

The Location of Samples and Sampled Areas in the Test Area.

The original placing of the grid determined sample locations at the center of each sampled area. It was necessary to shift the samples to their actual location, as shown by the black squares on the map, for the reasons explained in the text.

It is not essential that each sample be located in the exact center of its sampled area, and for that reason, the original boundaries of the sampled areas were retained even though the samples themselves were shifted.

LOCATION

OF INDIVIDUAL SAMPLES AND THEIR SAMPLED AREAS

which the sample centers had been marked, were sent to the National Photographic Library with the request that prints of those photographs having centers closest to the market points be made available. On receipt of the prints, some changes in sample location were necessary, because of the desirability of using only the central, undistorted portion of each print, and of not splitting one sample between two photographs. Figure 12 shows the final location of the samples, shifted somewhat from their preferred position at the center of the sampled area.

The twenty-eight sample blocks were numbered for reference purposes, as shown in Figure 12.[1] The samples provide a detailed coverage of fifty-six square miles, or approximately 10 percent of the total of 580 square miles in the area.

II. FIELD PROCEDURE.

Field work was completed in two periods; June 16th. to 22nd., and August 19th., to September 21st., 1948.[2] The samples

---

(1) In the numbering system adopted, provision was made for a possible extension of the grid as far east as the Richelieu River.

(2) The dates on which each sample was studied, with base location used, are as follows:

HOWICK	ATHELSTAN	HEMMINGFORD	DUNDEE CENTER
16 June: #28	19 Aug: # 5	1 Sept: #18	14 Sept: # 3
17 " #28	20 " # 4	2 " # 8	15 " #22
18 " #29	22 " # 6	3 " #17	16 " #26
19 " #27	23 " # 7	4 " # 9	17 " # 2
20 " #40	24 " #20	6 " #16	18 " # 1
21 " #30	26 " #21	7 " #10	19 " #23
22 " #39	27 " #19	8 " #15	20 " #25
			21 " #24

were studied at the rate of one each day, excluding days of inclement weather on which no work was possible. Each sample required, on the average, six hours for detailed mapping, the mapping being done mainly on foot. Travelling to and from samples was done by bicycle, using whenever possible an alternative route for each trip. In this way, over seven hundred miles of road were traversed.

The Notation System. Figure 13 is a reproduction of a typical, completely-mapped sample. Land uses and physical conditions are recorded on the air photo by means of a fractional code. Each parcel of homogeneous land use and physical conditions is enclosed by a line, and an indicator fraction is written within the enclosed area. In each fraction, the letters and figures of the numerator indicate the land use, and those of the denominator indicate physical conditions or terrain type. A new area was mapped and a new fraction recorded whenever a change occurred in any one single factor making up either numerator or denominator.

The complete fractional code as used in the survey is given in Table I.[3] Six primary categories of land use are given: cropped land, pasture land, land in natural vegetation

---

(3) It should be noted that this fractional code is not presented as a finished product suitable for use in any area. The code was adapted to suit the characteristics of this particular area and the objectives of the survey. Although some changes in notation were made as field work progressed, the final results are nevertheless strictly comparable as between one sample and another.

Figure 13.

A Typical Sample, Mapped on an Aerial Photograph

The boundaries of the sample were blocked off on the aerial photograph, and land uses and physical conditions were recorded by means of the fractional code. The legend at the right side of the photograph gives the complete six-digit characterization of the terrain types found in the sample. The sample reproduced is No. 2, located in a clay and ridge plain land type. (The illustration is one-half the size of the original photograph.

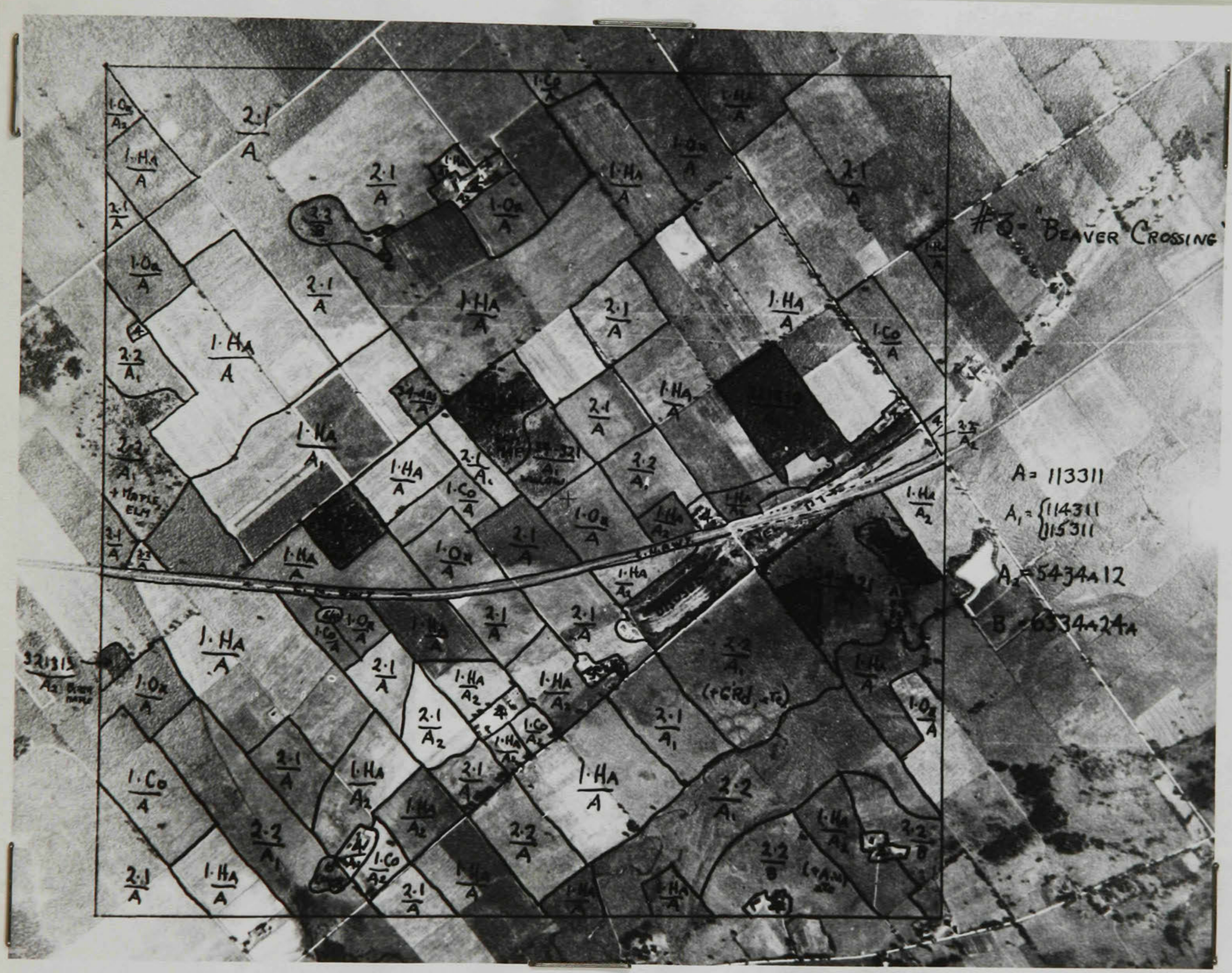

#3 - "BEAVER CROSSING"
A = 113311
A1 = {114311 115311
A2 = 5434A12
B = 6534A24A

TABLE I THE FRACTIONAL CODE

<table>
<tr><th colspan="2">N U M E R A T O R</th></tr>
<tr><th>First Digit</th><th>Second Digit</th></tr>
<tr><td>1. Cropped Land</td><td>Ha - Hay
Oa - Oats
Ba - Barley
Bu - Buckwheat
Co - Corn
Pe - Peas
Be - Beans
Tu - Turnips
Po - Potatoes
To - Tomatoes
Ap - Orchards
Fr - Small Fruits
Fl - Flax
Pl - Plowed
Veg - Small Farm Gardens</td></tr>
<tr><td>2. Pasture Land</td><td>1. Improved or Rotation
2. Unimproved or Rough
2+. Rough, being invaded by trees or shrubs.</td></tr>
<tr><td colspan="2">3. Natural Vegetation Areas
This category includes areas of forest or woodlot, as well as areas of shrubs, herbs, or reeds. (As explained in Chapter VII, further digits of this category are to be disregarded.)</td></tr>
<tr><td colspan="2">4. Built-up Land
This category includes farm yards and buildings, roads (except farm roads), and railways. The items are not differentiated by further digits.</td></tr>
<tr><td colspan="2">5. Waste Land
This category includes any land, except natural vegetation areas, not used for agricultural activities. Separate items are not differentiated by further digits, but the actual item in each case should be noted on the map.</td></tr>
<tr><td colspan="2">6. Idle Land
This category includes any land, normally noted by a first digit of 1 or 2, that has apparently been abandoned or allowed to lie idle.</td></tr>
</table>

TABLE I THE FRACTIONAL CODE (Continued)

D E N O M I N A T O R

First Digit: Physiographic Type

1 - Clay Plain
2 - Sand Plain
3 - Bog or Half-Bog
4 - Floodplain
5 - Beach and Terrace
6 - Rough Moraine
7 - Rock Outcrop
8 - Unidentified

Second Digit: Topography

1 - No Appreciable Slope
2 - Slightly Rolling
3 - Strongly Rolling
4 - Uniform Gentle Slope
5 - Uniform Strong Slope
6 - Very Steep Slope
7 - Gullied

Third Digit: Drainage

1 - Excess Surface Drainage, erosion of topsoil
2 - Excess Subsoil Drainage, topsoil normally dry
3 - Good
4 - Fair, Some Ill-drained patches
5 - Poor, topsoil normally saturated

Fourth Digit: Soil Material

1 - Sand
2 - Loam
3 - Clay
4 - Sandy Clay
5 - Sandy Loam
6 - Muck or Peat
7 - Gravel
8 - Clay Loam

(An " a " following this digit denotes the presence of gravel.)

Fifth Digit: Depth of Soil to Bedrock

1 - Deep, over 6 feet
2 - Medium, 3 to 6 feet
3 - Shallow, less than 3 feet

Sixth Digit: Stoniness of Soil

1 - No stones
2 - Some Stones, but no interference with cultivation
3 - Stones, some interference with cultivation
4 - Too Stony for cultivation

(An " A " following this digit denotes the presence of boulders.)

other than pasture, built-up land, waste land, and idle land. Each of these primary categories is indicated by the first, or left hand, digit in the numerator: cropped land, 1; pasture, 2; and so forth. Further subdivision of some categories was accomplished by means of the additional digits shown in the Table.

The denominator of the fraction records terrain types in similar fashion. It was found, however, that only a limited number of distinct terrain types were ever identified in any one sample, so that the denominator could be abbreviated. A letter was substituted for the six-digit denominator of each terrain type, and a key to the types was marked in the margin of the map, as in Figure 13.

By this means, land uses and physical conditions were easily recorded and transcribed. For example, a parcel of land is noted (see Figure 13) as:

$$\frac{2.1}{A}$$

Denominator: A 113311 (from key on margin of map)

First Digit: 1 . . . . Clay plain physiographic type.
Second Digit: 1 . . . . Slightly rolling topography.
Third Digit: 3 . . . . Good Drainage.
Fourth Digit: 3 . . . . Clay Soil.
Fifth Digit: 1 . . . . Deep Soil, over 6 feet in depth.
Sixth Digit: 1 . . . . No Stones.

Numerator: 21

First Digit: 2 . . . . Pastured.
Second Digit: 1 . . . . Cultivated (Rotation) type.

<u>A Typical Day in the Field.</u> Preparation for each day's field work began with an inspection of the aerial photograph of the sample. Soil maps and topographic sheet were examined in conjunction with the photograph, to obtain a general idea of the type of terrain and possible physiographic or land use boundaries in the area.

En route to the sample area, frequent observations were made of land use and terrain types, in terms of uses and types that had been identified in other samples. Photographs were taken of typical landscapes as well as of points of special interest, and notes were made as to the prosperity and size of farms, the condition of buildings, the kind of cattle and size of herds, the state of crops, the condition of woodlots, and in general, any matter that seemed of importance. All of these observations were recorded in the field note-book, and each point of observation was marked on the topographic map.

On arrival at the boundary of the sample, a convenient starting-point for the detailed study was chosen; usually, a farmhouse where information about conditions in the area could be obtained. Mapping was then begun, on foot.(1)

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(1) The mapping was done by writing the fraction and marking the area boundaries on a sheet of transparent plastic that had been fitted over the aerial photograph. The photographs used were of excellent quality, so that the position of the observer could easily be ascertained from numerous minor landmarks such as isolated trees, buildings, paths, and hedgerows. Field boundaries also showed up well in the photographs. It was found that these boundaries seldom had changed, although the crops grown might obviously be different, from what they were at the time the photographs were taken.

For the first few fields, tentative terrain types were recorded to six digits, until the distinctive types of the area became apparent. Then, as mapping progressed, the terrain type for each use could easily be identified as A, B, C, and so forth, by noting one or two key characteristics. This practice saved considerable time in mapping, but complete six digit checks were made periodically, to ensure that accuracy was being maintained.

Most of the land uses could be identified on sight. As a general rule, each cropped field was seen, although not necessarily at close range. Experience showed that high accuracy was maintained even though crops were identified from one or two fields away by using such indicators as colour and texture. Pasture uses were treated in the same manner, but it was found impracticable to attempt visiting every part of forested or other natural vegetation areas. In these cases, much reliance was placed on an interpretation of the aerial photographs so as to be certain that the conditions noted at one or two points in such an area extended over its entirety.

When the greater part of the sample had been mapped in this fashion, an attempt was made to secure one or two typical photographs. Field-by-field mapping was then completed, and a careful inspection of the finished sheet was made to see that no area had been left out or incompletely recorded. The terrain types were reconsidered at the same time, and any necessary changes in notation were made.

On the return route to base, observations were made in the same manner as on the way out; except, of course, in cases where the route had been travelled previously. Back at base, the final step in the day's work was to transfer the mapped information from the transparent sheet directly onto the face of the photograph in permanent India ink.

Field work was considered completed when all the samples had been mapped, except for two additional reconnaissance trips to areas which had been inadequately traversed. The office stage of the investigation then began, in which the first step was to obtain land use totals and check the accuracy of the sampling as described in the next chapter.

Chapter VII.

THE QUANTITATIVE RESULTS FOR THE TEST AREA

The quantitative results of sampling in the test area, together with some discussion of the methods of measurement that were used and possible sources of error, are presented in this chapter. Data for the amounts of land use and terrain types in each sample are given in tabulated form, and these are averaged to give figures for the area in general

I. MEASUREMENT OF THE INDIVIDUAL SAMPLES

A planimeter was used to measure the area on the aerial photographs of the individual parcels of land use making up each sample.[1] These areas were read to the nearest hundredth of a square inch, and entered on a data sheet. A specimen data sheet is shown in Table II.

<u>Instrumental and Observational Error</u>. Some instrumental and observational errors undoubtedly occurred. However, this error was kept to a minimum by carefully measuring the total area of the sample several times and averaging the result. This

(1) The instrument used was an Allbrit Polar Planimeter, which reads directly to one tenth of a square inch, with a vernier scale for reading hundredths.
On an average, about 500 readings per sample were required. The time involved in measurement, plus the time required for calculations and tabulations, amounted to about three hours per sample.

TABLE II

SPECIMEN DATA SHEET

Sample #26 - "Landreville"

Total Measured: 3150
Total Added: 3118
Error: 32; % Error 1.0

Area in Square Inches

Use Type	- 1 -								- 2 -			- 3 -		- 4 -	5	6	Total
Land Type	**Ha**	**Oa**	**Bu**	**Co**	**Be**	**To**	**Veg**	**Pl**	**21**	**22**	**22+**	**Code**	**Area**				
A 114411	0.76 0.29 0.06 0.08 0.06 0.68 0.09 2.08 0.16 0.70 0.38 0.50 0.14 0.16 0.07 0.05 0.50 0.53 0.51 0.59 0.91 9.30	0.15 0.09 0.28 0.28 0.24 0.32 0.10 0.20 0.59 0.38 0.20 0.07 0.11 0.14 0.20 0.07 3.42	0.11 0.11 0.10 0.10 0.09 0.32 0.15 0.08 1.06	0.41 0.02 0.06 0.33 0.18 0.15 0.05 1.20	0.05 0.05	0.04 0.04 0.05 0.10 0.09 0.10 0.42	0.12 0.06 0.07 0.25	0.12 0.12	0.40 0.13 0.19 0.19 0.16 0.08 0.09 0.20 0.20 0.18 0.21 0.12 0.20 0.20 0.22 0.21 0.08 0.30 0.26 0.18 0.15 3.95	0.06 0.06	0.09 0.06 0.20 0.16 0.51			0.03 0.08 0.02 0.04 0.02 0.19			20.53
A1 115411										0.31 0.10 0.28 0.69	0.22 0.22						0.91
B 6234A24A										0.26 0.02 0.03 1.79 0.14 0.10 0.17 0.11 0.16 0.04 0.05 2.88		319313 311413 33-311 34-421 329401 311113 329201 321110 322210 322240 325411 331221 33-300 311213 33-411 321210 329403 33-321 322214	0.11 0.27 0.10 0.51 0.50 0.07 2.22 0.35 0.27 0.06 0.28 0.21 0.12 0.08 0.10 0.07 0.32 0.17 0.21 0.39 0.28 6.69	0.01 0.04 0.02 0.06 0.02 0.02 0.17			9.74
Total	9.30	3.42	1.06	1.20	0.05	0.42	0.25	0.12	3.95	3.63	0.73		6.69	0.36	-	-	31.18

figure was then compared with the sum of the individual parcel areas.[2] If the discrepancy between the two figures exceeded three percent, the results were discarded and all measurements were done over until the error was reduced below the tolerated error. The average absolute error of measurement and observation for all twenty-eight samples was $\pm$ 1.3 percent.[3]

II. SUMMARY DATA FOR LAND USE AND TERRAIN TYPES.

A complete statement of the quantitative data for land use and terrain types in the test area would require, of course, twenty-eight data sheets. Such a mass of data is obviously unmanageable, so that some generalizations of land use and terrain types are required.

Generalization of Terrain Types. In the course of the detailed sample studies 105 terrain types were identified. Many of these differ from one another by only a few digits in the denominator, so that it was found possible to group similar types together into eight generalized categories. The identified

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(2) Arithmetical errors were kept to a minimum by cross-adding or double checking the computations.

(3) The greatest instrumental error occurs in the measurement of very small parcels. For any parcel up to 0.05 sq. in. in area, it was found that greater accuracy was obtained by visual estimate than by the use of the instrument.

To reduce instrumental error due to slipping, a special device was developed: A thin glass plate was covered with a sheet of heavy cellophane, and the photograph placed under the glass. The cellophane gave the required traction for the instrument, while the glass provided a smooth surface and held the photograph flat at the same time.

types, listed according to general categories, are given in Appendix B.

Generalization of Land Uses. Since a complete breakdown of crop and pasture land use was necessary for comparison with statistics, these categories of land use were not generalized at this stage. This consideration did not apply to natural vegetation, however, and the identified types were lumped together under the one heading.(4)

Elimination of Scale Error. Before the land use data for the entire area could be summarized, it was first necessary to eliminate errors arising out of differences in the scale of the aerial photographs. While the scale of the photographs

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(4) Some explanation of the special nature of the vegetation studies undertaken in this thesis seems necessary here. The field studies afforded an excellent opportunity to experiment with various methods of classifying, coding, and generalizing natural vegetation types for geographic purposes. As a result of experience gained during the first period of field work in June of 1948, existing methods of studying natural vegetation were felt to be unsuitable. The method of study used in the second period of work differs radically from that used in the first period. A new method was worked out in the interim, after consultations with Dr. Dansereau.

The specialized vegetation study was not, however, an integral part of the thesis problem. Consequently, the method is not discussed here, for it only indirectly affects the main problem of this thesis. Although it would have been desirable to give some breakdown of natural vegetation types, this was not possible, because the different methods used give breakdown figures which are not strictly comparable. But Total figures for natural vegetation remain unaffected, so that only these total figures appear in the summary statements of land use.

was nearly uniform, there were some differences due to variations in the altitude of the aircraft, or to variations in the focal lengths of the cameras used.

Since the scales differ slightly between photographs, the area of each sample as measured on the photographs also differs. This follows from the fact that each sample covers the same area - - two square miles - - on the ground. On the photographs, however, land uses are measured in square inches. If, because of scale differences, one sample totals more square inches than another, the breakdown data are not comparable - - obviously, the larger sample will have too much weight when the data for all samples are added together.

For the above reasons, the figures for each sample were converted to percentages of unit area. Since each sample is indeed a unit area - - two square miles - - the data were thereby made comparable, and scale error was eliminated from the summary figures for the whole area.

The Summary Statements. Summary statements of land use and terrain types are presented as Tables III and IV, which give the somewhat generalized breakdowns for individual samples and the average of all samples. These tables contain the quantitative data upon which an analysis of land use in the test area can be based. They also afford a basis for comparing the sampling results with available statistics. This comparison, whereby the accuracy of the sampling method is ascertained, is made in the following chapter.

TABLE III

PERCENTAGE USE COMPOSITION OF EACH SAMPLE AND AVERAGE FOR TOTAL AREA

SAMPLE	HA	OA	BU	BA	CO	PE	BE	TU	PO	TO	VEG	AP	FR	PL	21	22	22◇	3	4	5	6
1	14.96	2.08			1.06									0.56	0.25	16.29	7.83	56.20	0.62		0.22
2	40.40	6.79			3.48										22.35	9.64	5.44	6.82	2.39	0.06	2.56
3	17.73	3.15										0.38		0.35	10.57	20.82	2.79	42.60	1.62		
4	11.23	0.70		0.32											4.25	8.72		73.20	0.79	0.79	
5	13.72	3.55			3.68										4.09	1.90		71.60	0.68	0.77	
6	16.14	0.55			3.84				0.10			6.23	0.06		2.94	19.34	6.53	43.40	0.71	0.23	
7	17.42	1.90										0.79			0.98	17.06	10.09	51.10	0.70		
8	14.32	1.53	0.91		0.39							5.36				34.90		40.90	1.86		
9	24.60	4.35			2.61						1.32	9.80	0.31		0.48	16.06		39.15	1.09	0.23	
10	15.11	3.04			1.12							3.52			0.67	10.87	13.60	51.40	0.58		
15	21.05	6.00	0.81		2.26				0.29		0.26	1.45			1.22	13.40	8.87	42.70	1.18		0.55
16	23.26	4.93	0.22		2.48						0.48	1.27			0.16	24.55		41.25	0.76		0.54
17	16.48	3.64	1.12		0.96							0.19			0.13	17.76		58.80	0.38		0.45
18	40.90	13.75	3.22		7.09			0.91			0.31	0.84		0.87	11.32	7.38		10.27	1.81		1.16
19	13.26	2.11			0.32										2.84	2.49		78.40	0.19	0.47	
20	16.87	4.94	1.86		0.66										5.07	2.26		68.30	0.03		
21	41.50	11.03	0.44		3.85						0.28				19.67	4.86		11.86	2.77	3.56	
22	14.83	0.60			0.31										1.85	20.24	4.04	56.30	0.70		0.73
23	43.20	12.86			1.24						0.16			0.41	16.37	7.91	7.08	8.84	1.40		0.61
24	20.24	5.14	1.00	0.94	0.85						0.19	1.56			8.56	8.17	7.90	39.40	0.44	3.45	1.82
25	29.65	7.03	1.54		5.29					0.42	1.03			1.67	11.83	9.24	8.70	21.95	1.25		0.45
26	29.83	10.97	3.40		3.85		0.16			1.35	0.80			0.38	12.67	11.64	2.34	21.45	1.15		
27	39.45	19.55			8.16	0.23					0.38	0.35			19.97	4.29		6.06	1.57		
28	42.00	16.93			6.10						0.42	0.18			23.90	5.65		2.82	1.41	0.56	
29	36.90	13.22			4.58	3.87					0.25	0.14	0.89		15.00	9.50		7.82	3.74	4.23	
30	20.80	1.08			1.39		0.49		2.64		0.18	0.94			0.31	15.68		53.30	2.91	0.36	
39	39.65	15.48			1.50		0.45		0.19	0.08	0.26	0.38			5.04	20.50		13.48	1.92	1.00	
40	37.35	27.75			4.78	0.95					0.15		2.44		19.44	4.17		0.80	0.42	1.56	0.23
TOTAL	712.85	204.65	14.52	1.26	71.85	5.05	1.10	0.91	3.22	1.85	6.47	33.38	3.70	4.24	221.93	345.29	85.21	1020.17	35.07	17.27	9.32
AVERAGE	25.45	7.31	0.52	0.05	2.57	0.18	0.04	0.03	0.12	0.07	0.23	1.19	0.13	0.15	7.93	12.30	3.04	36.43	1.25	0.62	0.33

TABLE IV PERCENTAGE TERRAIN TYPE COMPOSITION OF EACH SAMPLE

Sample Number	Clay Plain	Ill-drained Clay Plain	Sand Plain	Bog and Half-bog	Beach and Terrace	Moraine Ridge	Rock Outcrop	Other
1	11.4			56.4		32.2		
2	63.1	22.0			11.2	2.9		
3	47.7					47.0		5.3
4	16.2					77.8		6.3
5					100.0			
6					100.0			
7					100.0			
8								1.9
9				17.2		75.3		7.7
10				31.5	30.8	37.6		
15				24.3	33.9	41.8		
16				36.2	14.9	48.8		
17				26.0		63.2	5.8	5.1
18	85.7					14.3		
19			21.8	25.0		42.0	11.2	
20	29.4					70.6		
21	82.2					17.8		
22				11.3		88.7		
23	74.8					25.2		
24	48.4			27.2		24.4		
25	60.6					39.4		
26	68.8					31.2		
27	88.3	0.4				11.3		
28	94.9					5.1		
29	86.6					13.4		
30				35.2		64.8		
39	31.7					68.3		
40	98.9	1.1						

Chapter VIII.

THE ACCURACY OF THE SAMPLING RESULTS IN THE TEST AREA.

Much of the background for this chapter has already been discussed in that part of the thesis dealing with the theory and description of the hexagonal sampling system. The tests of accuracy which were described therein are applied, in this chapter, to the quantitative results for the Huntingdon-Chateauguay area. Three separate tests are applied, from which conclusions are drawn regarding the accuracy of the method both in this particular case and for general use.

I. AN INDEPENDENT TEST OF SAMPLING ACCURACY

The first test of sampling accuracy is termed an "Independent Test". It is contrasted with other tests which are based on a comparison between sampling and census data. The independent test uses the sampling data alone: its purpose is to ascertain what variation would result if a smaller number of samples had been studied.

Description of the Test. To make this test, the samples were divided into two groups -- even-numbered samples in one group, odd-numbered samples in another. Each group of samples thus represents the entire area, with in both cases a fairly even distribution of samples, as can be seen from Figure 12 (page 76).

Although the pattern that this distribution gives is not hexagonal, the results may be regarded as approximately those that a 14-sample hexagonal pattern would give. In this way two samplings, each representing 5 percent of the total area, may be compared with the original 10 percent sampling.

For each group of samples, new sets of average land use figures were computed, and these are compared with the average of all twenty-eight samples. The results of the test are presented in graphic and tabular form in Figure 14 and Table V.

<u>The Results of the Test</u>. In Table V. a close correspondence is shown for those land uses which occupy a fairly large proportion of the total area. Hay, natural vegetation, oats, and improved and rough pasture, all have close to the same average no matter whether fourteen or all twenty-eight samples are used.

The minor land uses, however, show quite a variation in the degree of correspondence between the two sets of averages. Corn shows a particularly close correspondence; built up land is almost equally good. Apples and peas, however, vary quite widely.

A partial explanation for this variance is to be found in the table of summary results (Table III) which gives the figures for individual samples. Compared with Table V, it will be seen that most of the minor uses which have a close corres-

TABLE V. RESULTS OF THE INDEPENDENT TEST OF SAMPLING ACCURACY

	All Samples	Odd Samples	Even Samples	Percent Deviation	Accuracy Index
Hay	25.45	26.39	24.52	3.6	96
Oats	7.31	7.57	7.05	3.5	97
Buckwheat	0.52	0.28	0.76	46.0	64
Barley	0.05	0.00	0.90	100.0	0
Corn	2.57	2.54	2.60	1.2	99
Peas	0.18	0.28	0.08	56.0	44
Beans	0.04	0.04	0.04	0.0	100
Turnips	0.03	0.00	0.07	100.0	0
Potatoes	0.12	0.03	0.20	75.0	25
Tomatoes	0.07	0.04	0.10	43.0	57
Vegetables	0.23	0.28	0.18	22.0	78
Apples	1.19	1.86	0.52	56.0	44
Fruits	0.13	0.09	0.18	38.0	62
Plowed	0.15	0.21	0.09	40.0	60
Improved Pasture	7.93	7.75	8.11	2.3	98
Rough Pasture	12.30	11.58	13.09	5.8	94
Invaded Pasture	3.04	3.24	2.85	6.9	93
All Vegetation	36.43	36.47	36.40	0.1	100
Built-up Land	1.25	1.37	1.14	9.6	90
Idle Land	0.62	0.73	0.50	19.0	81
Waste Land	0.33	0.16	0.50	82.0	18
All Pasture	23.27	22.57	24.05	3.4	97
All Improved	45.97	47.36	45.40	2.8	97

pondence are the ones that are widespread over the area. On the other hand, those minor uses with high deviations are the ones that occur in only a few areas.

This is confirmed by the field note-book. Peas, potatoes, and apples, according to traverse observations, are restricted to limited areas. Apples, for instance, are grown to any great extent only on the well-drained gravelly soils of the Adirondack slopes and on similar soils near Hemmingford and Port Lewis. Built up land, by contrast, occurs in almost the same proportion everywhere.

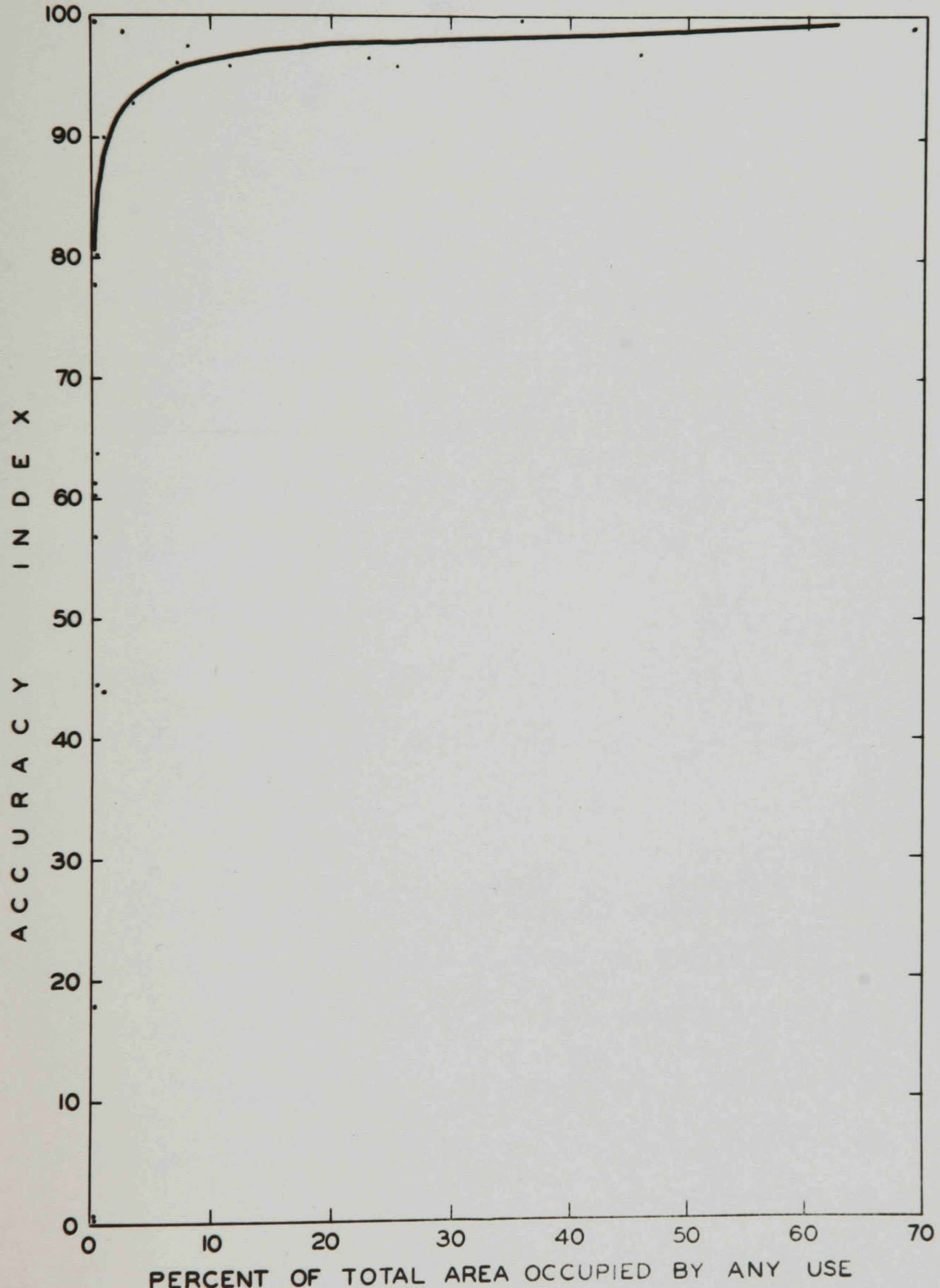
An Accuracy Curve. The accuracy of the sampling as shown by this test may be looked at in a slightly different, more quantitative way, by means of an accuracy curve (Figure 14). The curve was obtained in the following manner: For each use category the percent deviation of the 14-sample average from that of the 28-sample average was calculated. The most accurate sampling occurs when there is no deviation; therefore, an index of accuracy is obtained by subtracting the percent deviation from 100. The index for each particular use was then plotted against the percentage of the total area which that use represents. A series of points resulted, and a smooth curve was drawn.

These points, and the curve, show that the accuracy obtained was well defined for uses occupying 5 percent or more of the total area. For any use exceeding 10 percent coverage, the accuracy index is likely to be more than 95. For uses less

Figure 14.

A Curve of Sampling Accuracy in the Test Area.

The points shown were obtained by plotting the accuracy index against the percentage of the total area occupied, for each use listed in Table V. The curve suggests the general relationship between accuracy of sampling and the areal coverage of any use. It does not mean, however, that any 10 percent sampling of any area would produce results of this accuracy.



100
90
80
70
60
50
40
30
20
10
0
ACCURACY INDEX
0
10
20
30
40
50
60
70
PERCENT OF TOTAL AREA OCCUPIED BY ANY USE

than 5 percent, however, the accuracy varies widely and cannot be relied upon.

As has already been mentioned, the percent deviations used to determine the accuracy indices were calculated between a full mean of twenty-eight samples and a secondary mean of only fourteen samples. If additional samples were added to the original twenty-eight, means and deviations for this increased total could be calculated. For those uses which have already reached an accuracy index of 95, however, it is unlikely that the deviation would increase. It is to be expected, rather, that the deviation would be less -- for accuracy should increase as the number of samples increases. For this reason, it may tentatively be asserted that the accuracy curve represents the minimum accuracy obtained in this area for any total sample of 10 percent or more.

Relation of Accuracy to Evenness of Distribution. The conclusion is qualified as tentative because it has yet to be demonstrated that the accuracy obtained is not the result of accidental factors. If, for example, a particular use was so evenly distributed that it everywhere occupied the same percentage of the total area, then only one sample would be required to give 100 percent accuracy. Conversely, an unevenly distributed use, concentrated in one locality, would not be accurately reported unless a sample chanced to be placed in that particular locality.

A glance at the individual sample results (Table III) shows that none of the land uses in this area are perfectly distributed. In fact, there is quite a wide variation in evenness of distribution; very marked for minor land uses, and still considerable for the major uses. As a rough index of this variance, the percent mean deviation for each use was used. The greater the deviations of individual samples from the mean of all 28 samples, the less even is the distribution. This index was calculated for each use exceeding one percent or more of the total area; Table VI shows the comparison between this index and the accuracy index.

Logically, a three-way relationship between accuracy, evenness of distribution, and number of samples is to be expected. In this particular case, however, there are too few samples and too few land use categories for any such relationship to be statistically proved and defined.

II. CENSUS COMPARISON TESTS OF SAMPLING ACCURACY.

Another idea of the accuracy of the sampling results in the test area may be gained by comparing the sampling data with the census returns for the same area. In this section, two such tests are described: the first compares census and sampling figures for the whole area, the second compares figures for the single township of Hemmingford,(1) which approximates a

(1) The samples which comprise the homogeneous area are Nos. 9, 10, 15, and 16. See Figure 6, p. 58, and Figure 12,

TABLE VI. COMPARISON OF PERCENT MEAN DEVIATIONS AND ACCURACY INDICES FOR SOME LAND USES OCCUPYING MORE THAN ONE PERCENT OF THE TOTAL AREA

	Percent Mean Deviation	Accuracy Index
Hay	71.4	96
Oats	77.4	97
Corn	73.7	99
Apples	124.9	44
Improved Pasture	86.9	98
Rough Pasture	52.7	94
Invaded Pasture	116.7	93
Natural Vegetation	56.6	100
Builtup Land	54.9	90

homogeneous land use region. The results of both tests are summarized in Table VII.

Comparability of Census and Sampling Data. Before proceeding to a discussion of the results of the tests, some preliminary remarks on the comparability of census and sampling data are necessary. In this connection, a number of difficulties arise: Non-comparability of some of the land use categories of the census and the survey; land use changes between the dates of the census and the sampling survey; non-correspondence between the census divisions and the entire sampled area.

Non-comparability of Land Use Categories. Despite the complete breakdown of land uses which was used in this survey, it has been found impossible to fully correlate these land use categories with those of the census. Table VII shows the categories which were finally decided upon as being the most comparable and some variation is to be expected as a result. A full discussion of the way in which the categories of Table VII were developed, expected variations, and the methods of calculating the census figures, is given in Appendix C.

Land Use Changes between Dates of Census and Survey. Eight years elapsed between the census and the sampling survey, and it is known from interviews in the field that considerable changes in land use occurred during that time. These changes have resulted from economic pressures of the war and post-war period, technological improvements in crops and farm practises, and response to variations in the climate.

TABLE VII

RESULTS OF THE COMPARATIVE TESTS OF SAMPLING ACCURACY

	I M P R O V E D L A N D											UNIMPROVED LAND
	Total	F I E L D C R O P S					Market Garden	Orchard	Small Fruits	Improved Pasture	Other	Total
		Total	Hay	All Grains	Other Fodder	Pota-toes						
C O M P A R I S O N F O R T H E T O T A L A R E A -----												
SAMPLE DATA	47.07	36.28	25.45	7.88	2.60	0.12	0.29	1.19	0.13	7.93	1.25	52.10
CENSUS DATA	54.8	40.0	22.9	14.9	1.57	0.66	0.15	0.58	0.07	11.9	2.17	45.2
Difference	7.7	3.7	2.6	7.0	1.0	0.54	0.14	0.61	0.06	4.0	0.92	6.9
% Difference	16.4	10.2	10.2	89.0	38.4	450	48.0	51.0	46.0	50.0	74.0	13.0
C O M P A R I S O N F O R T H E H O M O G E N E O U S A R E A -----												
SAMPLE DATA	33.3	27.6	21.0	4.84	1.22	0.07	--	4.01	0.08	0.63	0.90	65.80
CENSUS DATA	36.8	30.3	21.1	8.15	1.32	0.68	--	1.30	--	3.57	1.70	63.2
Difference	3.5	2.6	0.1	3.31	0.10	0.61	--	2.70	0.08	2.94	0.80	2.6
% Difference	10.6	9.4	0.5	68	8.2	870	--	68	100	470	89	4.0

Non-correspondence between Census Divisions and Sampled Areas. Although the boundaries of the test area were chosen so as to give a statistical unit, there is some unavoidable divergence between these boundaries and those of the area that was actually sampled. Since the individual sampled areas are hexagonal, the outer edge of the total area is quite irregular, and in the test area, there is only rough coincidence with the statistical boundaries (Figure 12).

In some places, the total sampled area overlaps beyond the statistical area; in other places the sampled area does not extend to the edges of the political division, so that these places are unsampled. This may have little effect on the results in homogeneous areas where the overall amounts of overlap and underlap compensate each other. If, however, the area is not homogeneous, and if the overlap and underlap do not compensate, the discrepancy between sample and census data may be due to this effect and not due to sampling inaccuracy.(2)

General Reliability of Comparative Tests. The three factors described above will all tend to cause discrepancies between the survey and census data. Unfortunately, it is not possible to determine the quantitative influence of each factor on the results. It is better, therefore, to regard the comparative tests as a general guide to sampling accuracy than as a quantitative index of accuracy.

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(2) The discrepancy also depends on the size of the total area. Where the total area is very large and each sampl area comparatively small, the amount of overlap and und lap will not have much influence on average figures for total area.

<u>Results of the Comparative Tests.</u> Despite the many qualifications which apply to the comparative tests, several significant facts regarding sampling accuracy emerge from the results. The two tests -- one for the entire area, one for a homogeneous area -- afford a means of evaluating the hexagonal system's efficiency under two quite different conditions. In the homogeneous region, the effects of the occurrence and position of major land use boundaries are absent, whereas over the entire area these effects are fully operative.[3]

In general, it may be said that the sampling results are of the right order of magnitude, for both the entire area and the homogeneous region. No startling discrepancies are found in any of the land use categories when the absolute values of Table VII are considered. With the exception of cultivated pasture in the homogeneous area, the proportions of the land use pattern indicated by the census are paralleled by the sampling survey.

Correspondence between survey and census is closer in the homogeneous area than in the entire area. For every major land use, the absolute difference is less in the homogeneous area comparison. It is especially significant that this closer correspondence is general, for it tends to confirm the supposition

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(3) The results might have been more conclusive had it been possible to use several homogeneous areas. Only one township, Hemmingford, has boundaries sufficiently close to those of any homogeneous area for the test to be practical. Compare the locational map, fig. 6, and the map of land types, fig. 17.

that the sampling system is more accurate in a homogeneous area than in a less homogeneous one.

Finally, it should be noted that the minor land uses are not well indicated by the samples, except in one or two cases. This confirms the results of the independent test, which indicated that only random and accidental accuracy was obtained for minor uses.

III. OBSERVATIONS ON TEST RESULTS FOR SOME SPECIFIC CATEGORIES

The discrepancies for some of the major land uses are larger than might be expected in view of the results of the independent test. This should not be taken to mean that the independent test is invalidated, for in most cases there are specific reasons for suggesting that the discrepancies are not entirely due to sampling inaccuracy.

Improved Land. The discrepancy for improved land is large, when it is considered how many factors suggest that it should be quite small. In the field, the division between improved and unimproved land is distinct and easily recognizable; little evidence was found of any increase or decrease in its amount during the period 1941-48. The census and survey categories are quite comparable; it is the largest of the land use categories, and has a high accuracy index according to the independent test. Some of the discrepancy might be explained on the basis of non-correspondence of boundaries, but this should make little difference in the case of the homogeneous area.

Admittedly, a certain amount of sampling error must occur, but the possibility that the census is in error should be considered. Such an error is made possible by the census survey method, which depends for its acreage figures on estimates by the farmers. While most farmers know the exact total acreage of their land (because it has been surveyed and recorded) this is not usually the case for individual fields making up the farm. It is suggested that there is a tendency for the farmer to overestimate improved land; first, because of the natural human tendency to emphasize what is "best", second, because in the Farm Schedule the question about improved land is asked <u>before</u> the question about unimproved land, and third, because cleared fields appear larger to the eye than rough or wooded areas.

<u>All Grains.</u> The discrepancy in the all grains category is quite large in both cases. However, interviews with farmers revealed that there has been a substantial reduction in grain acreages during the last few years. This resulted mainly from economic conditions; the dairy-product price level increased, so that it was profitable to enlarge dairy herds and support them on grain and fodder imported from other areas. A secondary cause was a series of years with cold springs and wet harvest seasons. This created general discouragment concerning grain crops, so that fewer acres were sown to grain in the year that the survey was made than was usual in previous years.

<u>Orchard</u>. Under the stimulus of an increased market and the development of new horticultural practices, apply growing has

increased considerably in favoured parts of the area. Sample No. 6 had in 1948 as much orchard land with trees under ten years old as it had land with mature trees. This increase is typical of all apple growing regions and is undoubtedly the reason for the large discrepancy in this category between the census and the survey data.

Improved Pasture. The discrepancy for the category improved pasture is again larger than might be anticipated. It may be partly due to some confusion with hay (as explained in Appendix C), but in Hemmingford township especially it is felt that the survey would have revealed more improved pasture than it did, if the census figure of over 3 percent is correct. Very little improved pasture was found in the samples, and there are no indications from traverse observations that any extensive areas of improved pasture were missed.

In Hemmingford, some improved pastures may have been transformed into orchards during 1941-48. There is also a good deal of pasture reverting to bush, and it is possible that some farmers may have reported this land as plowable, despite its semi-abandoned condition.

Other Categories. It is tempting to point out that some categories have a close correspondence, and suggest that this indicates a high degree of sampling accuracy. This may indeed be the case, but there are too many factors influencing the results for the fact of accuracy to be demonstrated. Accuracy may be due to mere chance, but it is interesting to note that in the case of hay, as contrasted with other categories previously discussed, there was little reason to expect any great variations. Hay was rather easily identified in the field, and few changes in its acreage were mentioned by the farmers interviewed; the category is quite comparable, and it has a very high accuracy rating according to the independent test.

Summary. The comparative tests are not the most reliable guide to the accuracy of the sampling method, because of the several extraneous factors influencing the results, Nevertheless, the tests do indicate that the sampling method has come close to revealing average land use conditions over the entire test area, and that greater accuracy is obtained in homogeneous areas than in areas which are crossed by marked land use boundaries.

In some cases, specific reasons can be advanced in explanation of observed discrepancies, while in other cases there is little discrepancy to be explained. Unfortunately, the residual discrepancy -- that due to sampling inaccuracy alone -- cannot be quantitatively assessed.

IV. A MAP TEST OF SAMPLING ACCURACY.

Both the independent test and the comparative tests were devised to demonstrate the accuracy of the sampling method in ascertaining average land use values for the area studied. The results of these tests were satisfactory, but it has not yet been demonstrated that the sampling data can be used to interpolate and use conditions over the area, or, in other words, that maps of land use distribution drawn from sampling data will reflect the facts.

Description of the Test. If the interpolative picture which a distribution map of a certain use represents is correct, then it should be possible to measure the map and obtain the correct figure for the average intensity of that use. This figure can be compared with the average given by census data; if the interpolation has been accurate, there should be a close correspondence between the two averages.

An advantage of this test is that it eliminates the effect of non-correspondence between sampling and census boundaries, which was seen to be a disturbing factor in the comparative tests. Isoplethe need only be drawn, and areal measurements made, up to the edge of the census divisions. The average figure obtained by this test is rough, however, because of the small number of values for which isopleths are plotted.

The category hay was chosen as the one upon which to make this test, for it is the one which most nearly eliminates all extraneous sources of error, as indicated by the fact that it has the highest accuracy in both previous tests. Two distribution maps of hay were drawn: one with reference to physical conditions and traverse observations, and one on a purely statistical basis.(4) These maps are shown in Figure 15.

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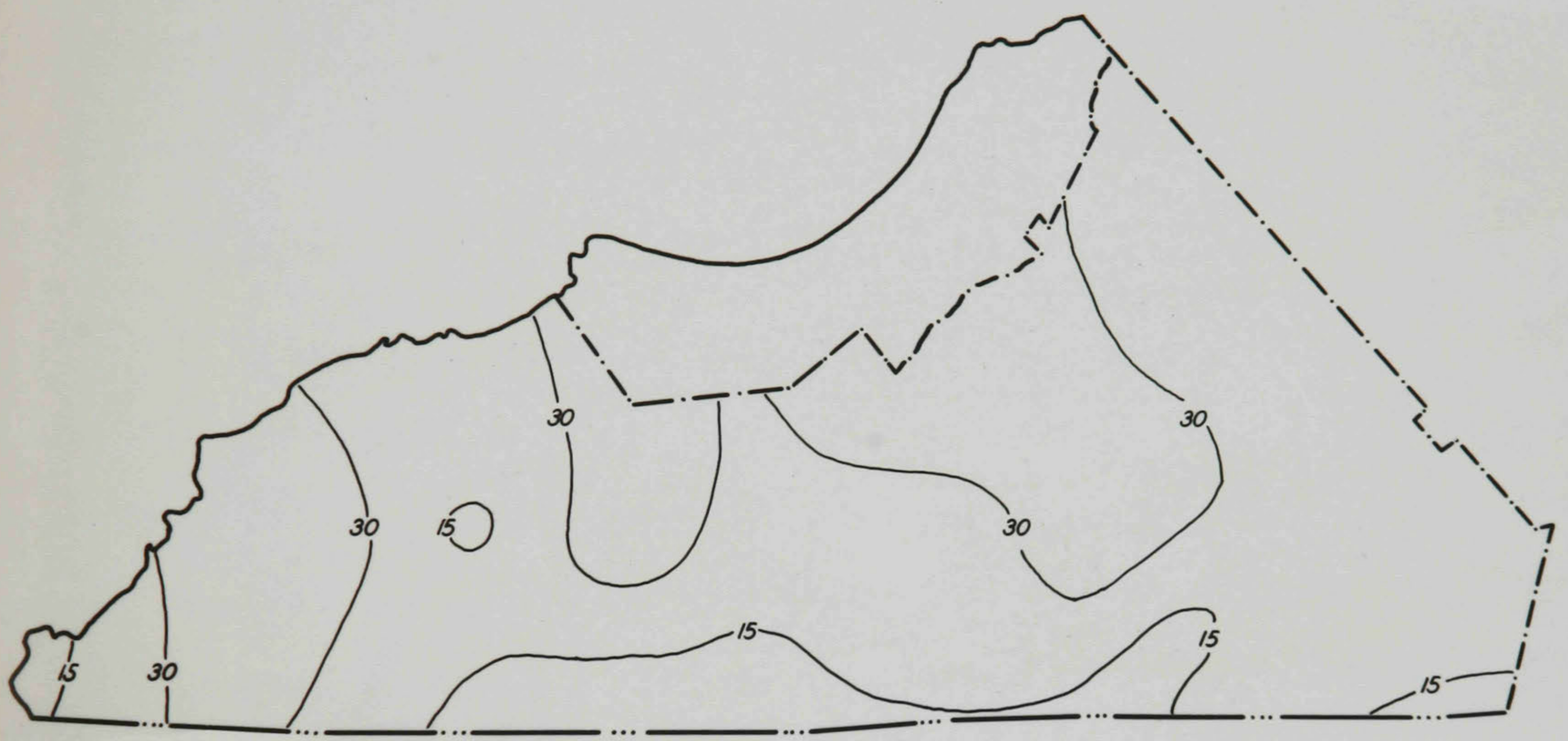
(4) See Chapter IV, p. 54 and Chapter IX, p. 127 for an explanation of the difference in the methods of drawing the two types of map.

Figure 15.

Hay as a Percentage of the Total Area, Showing the Contrast between Maps Drawn with and without Reference to Physical Conditions.

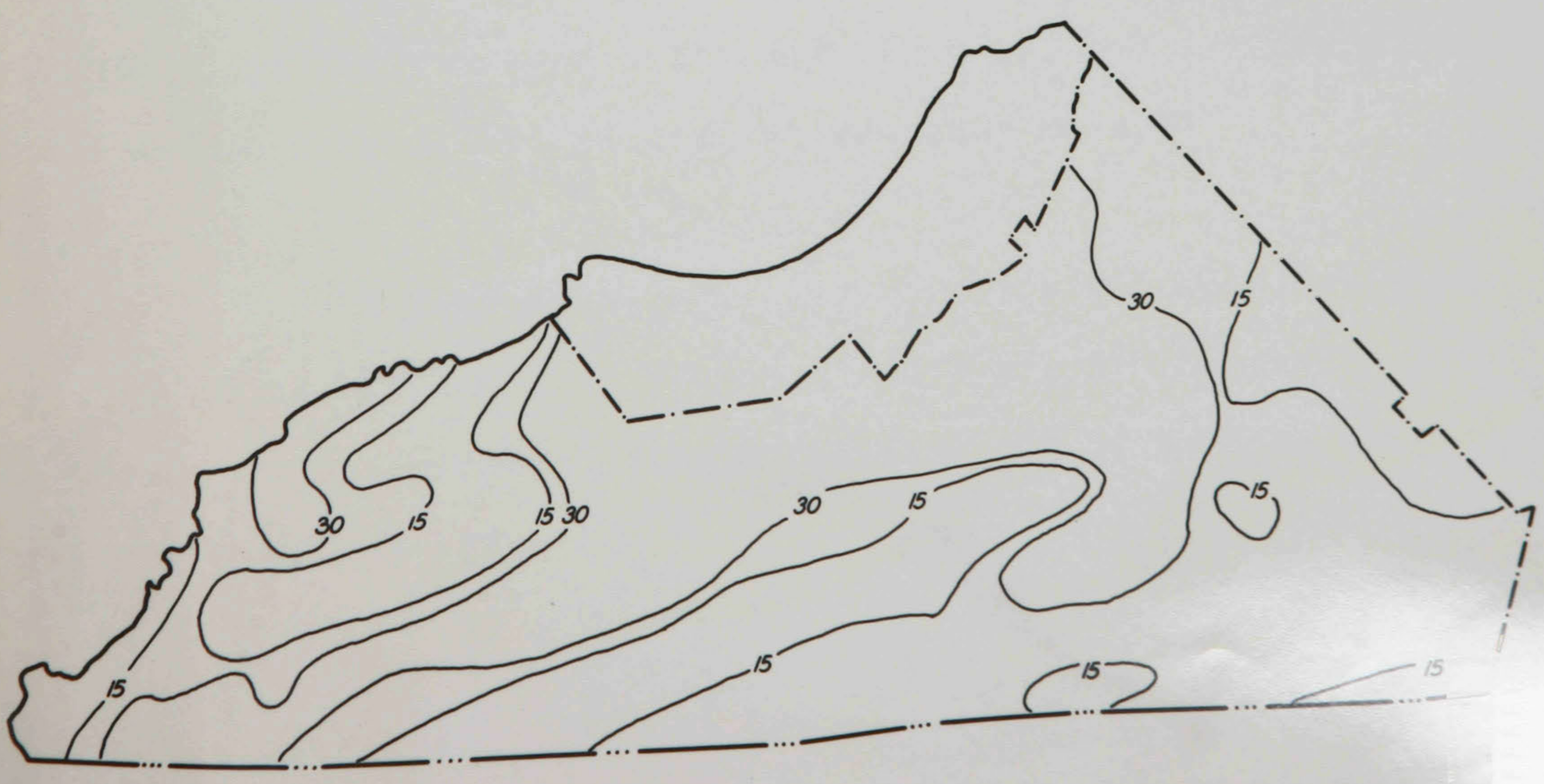
HAY *AS A PERCENTAGE OF THE TOTAL AREA.*

DRAWN WITH NO REFERENCE TO PHYSICAL CONDITIONS.



HAY *AS A PERCENTAGE OF THE TOTAL AREA.*

DRAWN WITH REFERENCE TO PHYSICAL CONDITIONS.



<u>Results of the Test.</u> There is a striking difference between the two maps, both in the distributional picture that they give, and the average figure obtained by measurement of each. The physically-based map shows hay as averaging 23 percent of the entire area, while the statistically-based map gives 28 percent. The census figure is 22.9 percent.

Traverse observations show that in many areas the statistically-based map is incorrect. The high concentration of hay shown in the western part of the area, in the vicinity of sample No. 23, does not in fact exist; the area is mainly an infertile sand plain with a high proportion of bush and waste land. The distribution is more exactly indicated by the physically-based map, which, of course, was deliberately drawn so as to be in accordance with traverse observations.

<u>Quantitative Effect of a Shift in Isopleth Position.</u> On both these counts, the physically based map is the more accurate. The question now naturally arises at to the degree of accuracy: What difference in the result would occur if the isopleths were shifted from their mapped position? That is, how precisely must the isopleths be placed to give an accurate result?

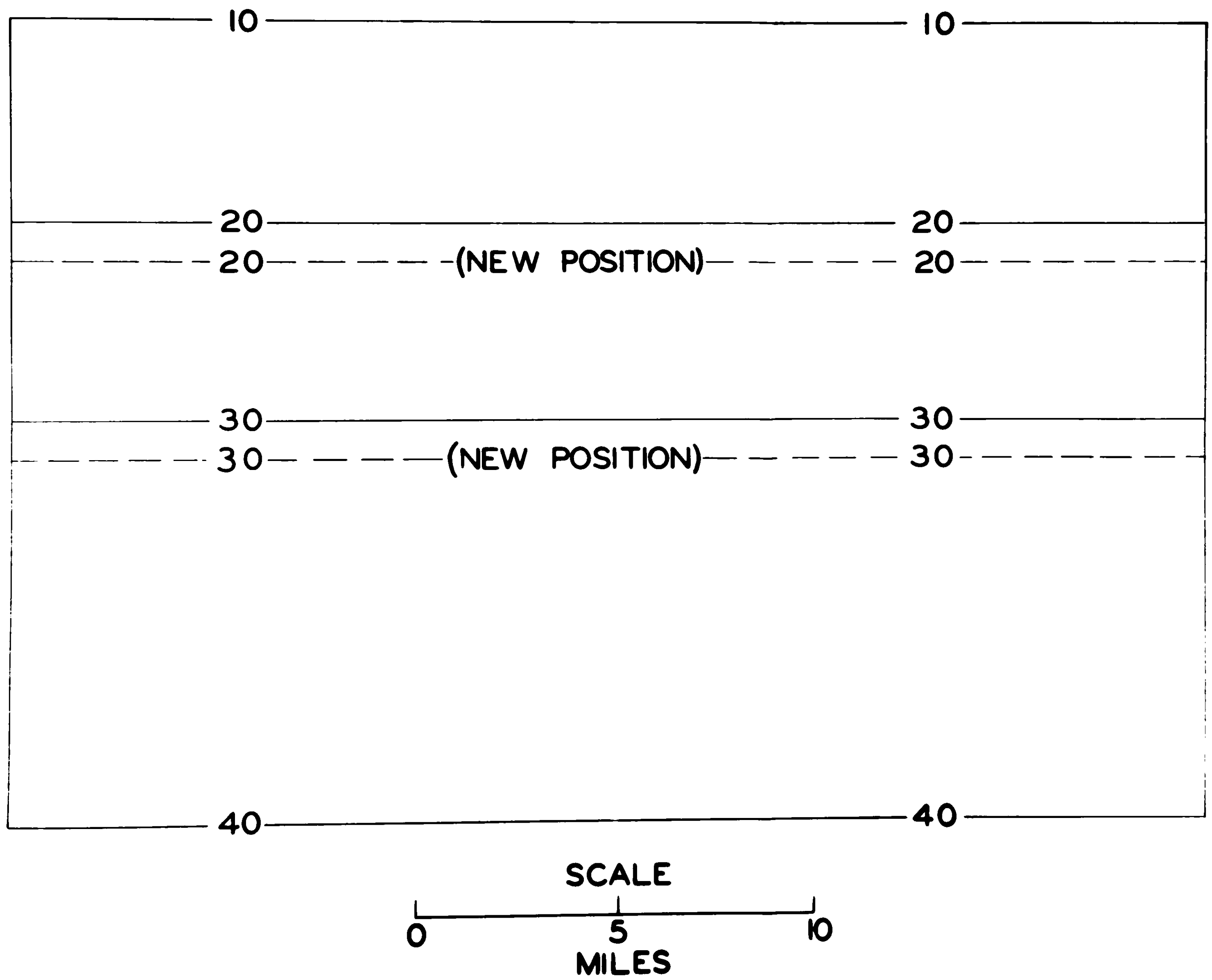
In the test area, the isopleths are rather complicated, so that it is difficult to assess the effects of changes in their position. A comparable, simplified case may be used to give some indication of the effect:

Figure 16.

The Effect of a Shift in Isopleth Position on the Figure for Average Intensity of a Land Use.

The figure shows a hypothetical area of 600 square miles (30 miles by 20) in which the isopleths of a certain use are shown in solid lines. The isopleths run from 10 percent of the total area at one edge, to 40 percent at the other, with the 20 and 30 percent isopleths also indicated.

By measurement of this map, the average intensity is calculated to be 27.5 percent. If the isopleths are shifted to the positions shown by the dotted lines, the new average is 26.5 percent, a difference of one percent. This indicates that a shift in isopleths is accompanied by an appreciable difference in the average figure, and hence, that when the average figure obtained is correct, the isopleths can be assumed to be in their correct positions.


10
10
20
20
20
(NEW POSITION)
20
30
30
30
(NEW POSITION)
30
40
40
SCALE
0
5
10
MILES

In Figure 16 is shown a hypothetical region of 600 square miles, in which the distribution of a land use is indicated by the isopleths of 0, 20, 30, and 40 percent. The average percentage was calculated in the way described above for the test area; for the distribution shown, the average is 27.5 percent. If the 20 and 30 percent isopleths are now shifted one mile to the new positions indicated by dotted lines in the diagram, a new average of 26.5 percent is found.

This tends to indicate that a shift in the isopleths of the test area map would be accompanied by a noticeable change in the average figure. The isopleths are probably in their correct positions to within an average distance of one mile. Actually, the case for the validity of interpolation does not rest so much upon this numerical basis as it does upon the experience gained in field work. The use of traverse observations makes it possible to place isopleths quite close to their correct position, the error in every case being probably no more than one mile.

Chapter IX.

THE EMPLOYMENT OF THE SAMPLING DATA IN LAND USE ANALYSIS

The final step in the development of the hexagonal sampling system was to test the applicability of the sampling data to land use analysis. The interpolative character of the system requires the use of some special techniques in drawing analytical maps, and at the same time it imposes some limitations upon the types of analysis that can be made.

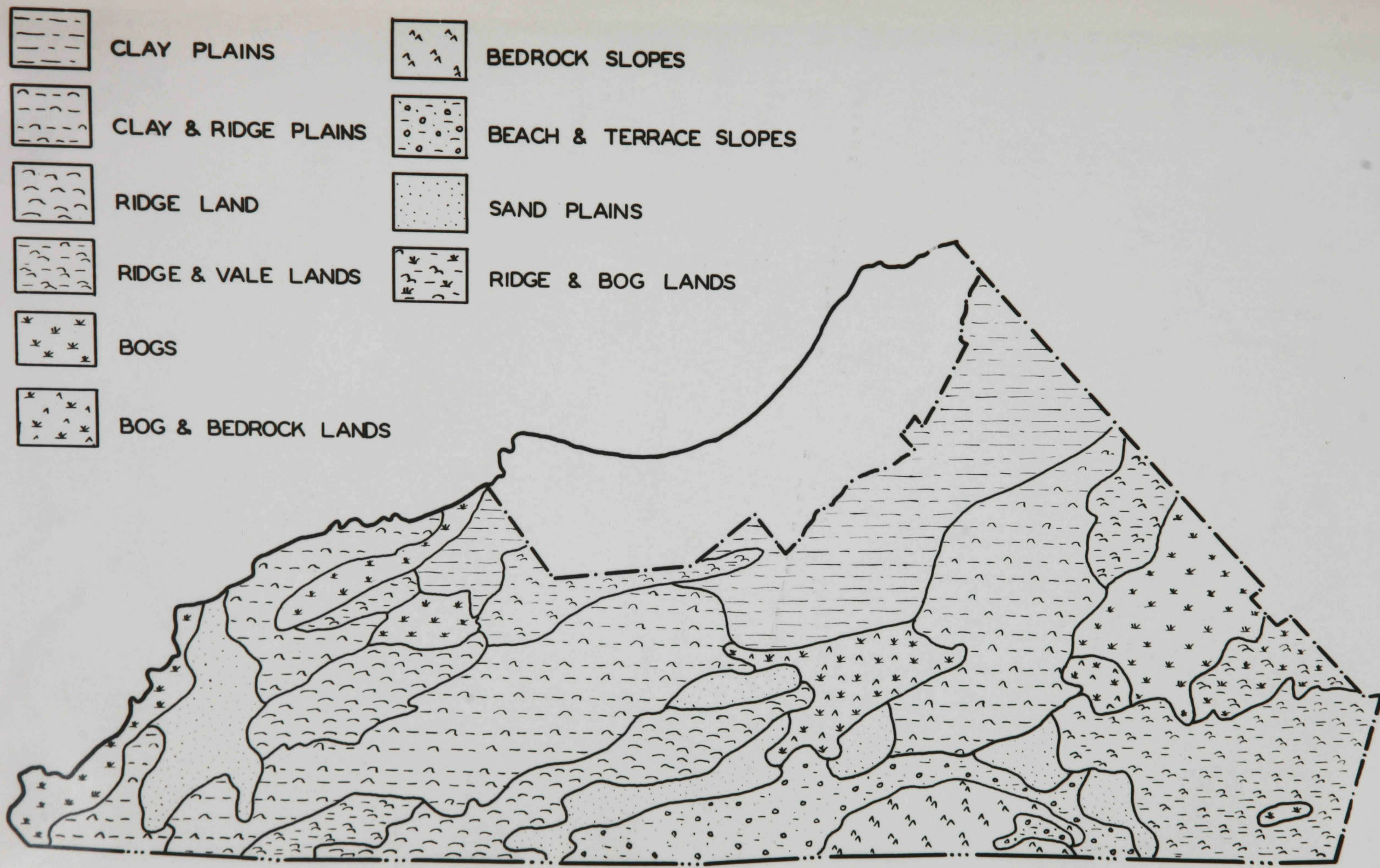
In this chapter, some examples of the various ways of using sampling data are given and the discussion centers on the possibility of defining land use patterns, relationships, and boundaries by means of the sampling data. The special techniques required for map drawing are described, and conclusions are drawn regarding the usefulness of the system as a basis for complete land use analysis.

I. A MAP OF LAND TYPES

The detailed sample studies revealed a number of characteristic associations of terrain types. These associations, termed land types, were defined primarily on the basis of the appearance of the landscape; but it was also found that definite land uses corresponded to each land type. The occurrence and distribution of the land types is shown in Figure 17.

Figure 17.

Land Types in the Test Area


CLAY PLAINS
CLAY & RIDGE PLAINS
RIDGE LAND
RIDGE & VALE LANDS
BOGS
BOG & BEDROCK LANDS
BEDROCK SLOPES
BEACH & TERRACE SLOPES
SAND PLAINS
RIDGE & BOG LANDS

LAND TYPES

<u>The Method of Drawing the Land Types Map.</u> The boundaries between land types, as indicated in Figure 17, are well defined. The land types themselves were defined and recognized through the sample studies, which revealed not only the terrain type associations but the land use patterns typical of each area. This degree of precision was only possible, however, because soil maps of the two counties were available.

The soil types as indicated on the soil maps were correlated with the terrain types identified in each sample. By this means, the soil maps were converted into terrain type maps, showing generalized terrain types for the entire area. This map then revealed not only the soils, but also the drainage, slope, and topography. The terrain type map was checked with traverse observations, and it was found that excellent correspondence was shown between the actual field observations and the mapped indications of terrain.

It was then possible to further generalize the terrain type map so that a map of land types resulted; with this map, there is no question of doubtful interpolation. As a final precaution,, the accuracy of the map was checked by traverse observations and by two reconnaissance trips made subsequently to the drawing of the map.

II. THE LAND TYPES.

<u>Clay Plains</u>. The clay plains are concentrated towards the northern part of the area, becoming especially widespread on

Figure 18.

A View on the Clay and Ridge Plains

In the foreground are cultivated fields and improved pasture land on heavy clay soils. Note the deep drainage ditch along the fence line. In the background are some small wooded patches on rough, stony moraine. View near Howick, Sample 28.

Figure 19.

A Farm in the Ridge and Vale Lands.

The rough stony area in the foreground serves as pasture while the rich soil of the level vale is used exclusively for crops. The far ridge is used for farmstead, woodlot, and pasture. View near Hemmingford, Sample 16.

Figure 20.

Rough Pasture Land on the Bedrock Slopes.

The shallow and uncultivable nature of the soil is evident from the photograph. The forest in the background is beginning to invade the cleared area. View near Sample 8.

Figure 21.

A Young Orchard on the Beach and Terrace Slopes.

The step-like character of the terrain can just be distinguished in the photograph. The soils are gravelly and well drained. View in Sample 8.

Figure 22.

Close View of a Beach, on the Beach and Terrace Slopes.

This beach occurs at 523 feet elevation, near Covey Hill. The rocks are flat fragments of Potsdam Sandstone, the bedrock into which the beach was cut. The woodlot in the background is grazed, as is evident from the lack of undergrowth and the clear-cut line along the lower branches of the trees. View near Sample 9.

Figure 23.

Close View of a Moraine Ridge

This pastured woodlot is on rough moraine with dolomite boulders. The blocky, angular appearance of the boulders indicates that they are of local origin. View near Sample 1.

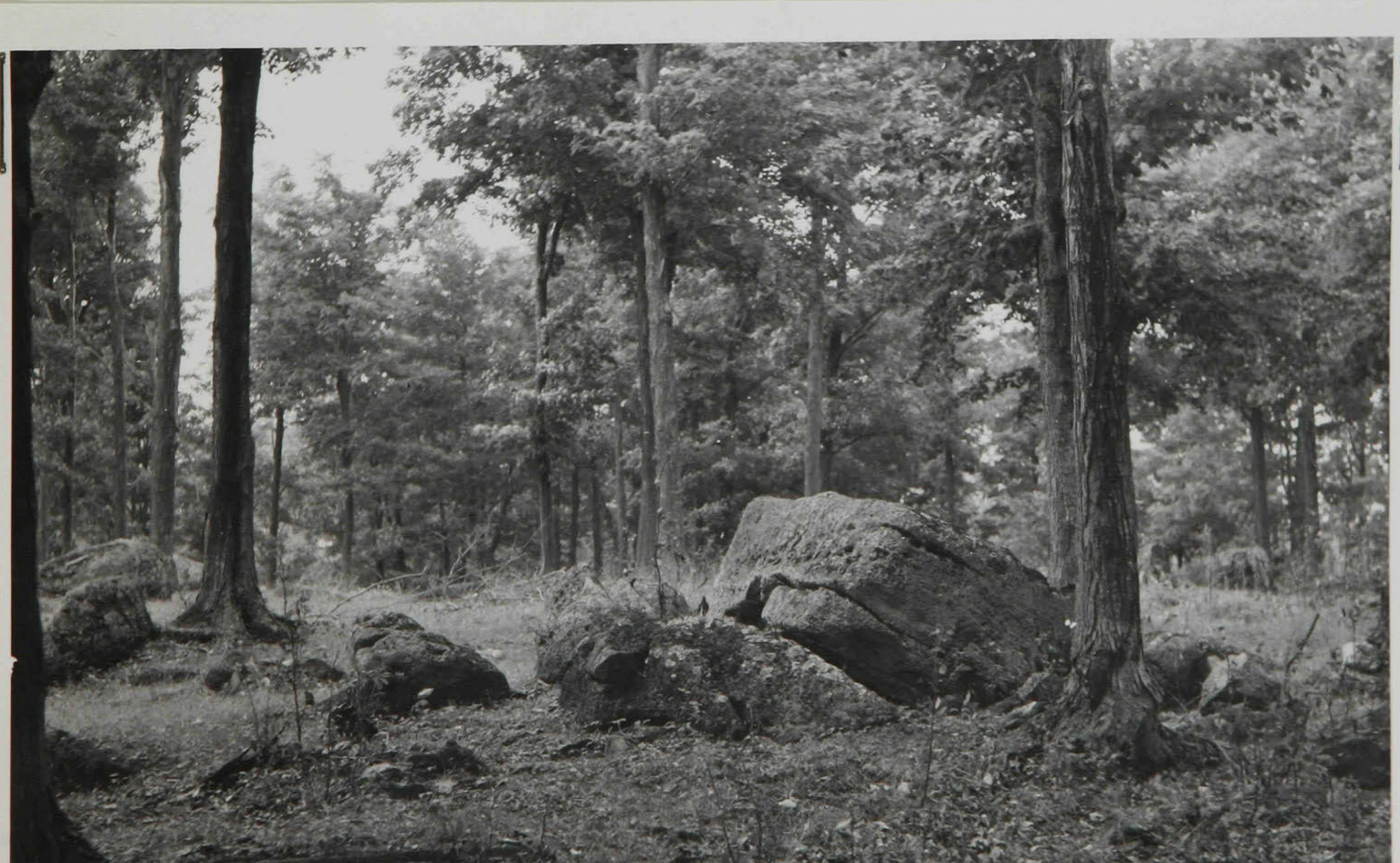


Figure 24.

A Typical View in the Bog and Bedrock Lands.

Only lichens and a few wire birch give a patchy covering to the flat, bare expanse of sandstone, but the boggy land in the background supports a mixed forest. The pines to the left are growing on a shallow sandy soil overlying the bedrock. View in Sample 17.

Figure 25.

Improving the Excavations for Drainage of the Bog Lands.

The bogs near Ste.Clothilde are being drained by deepening Norton Creek. Note the depth to which this shovel is excavating the solid sandstone.

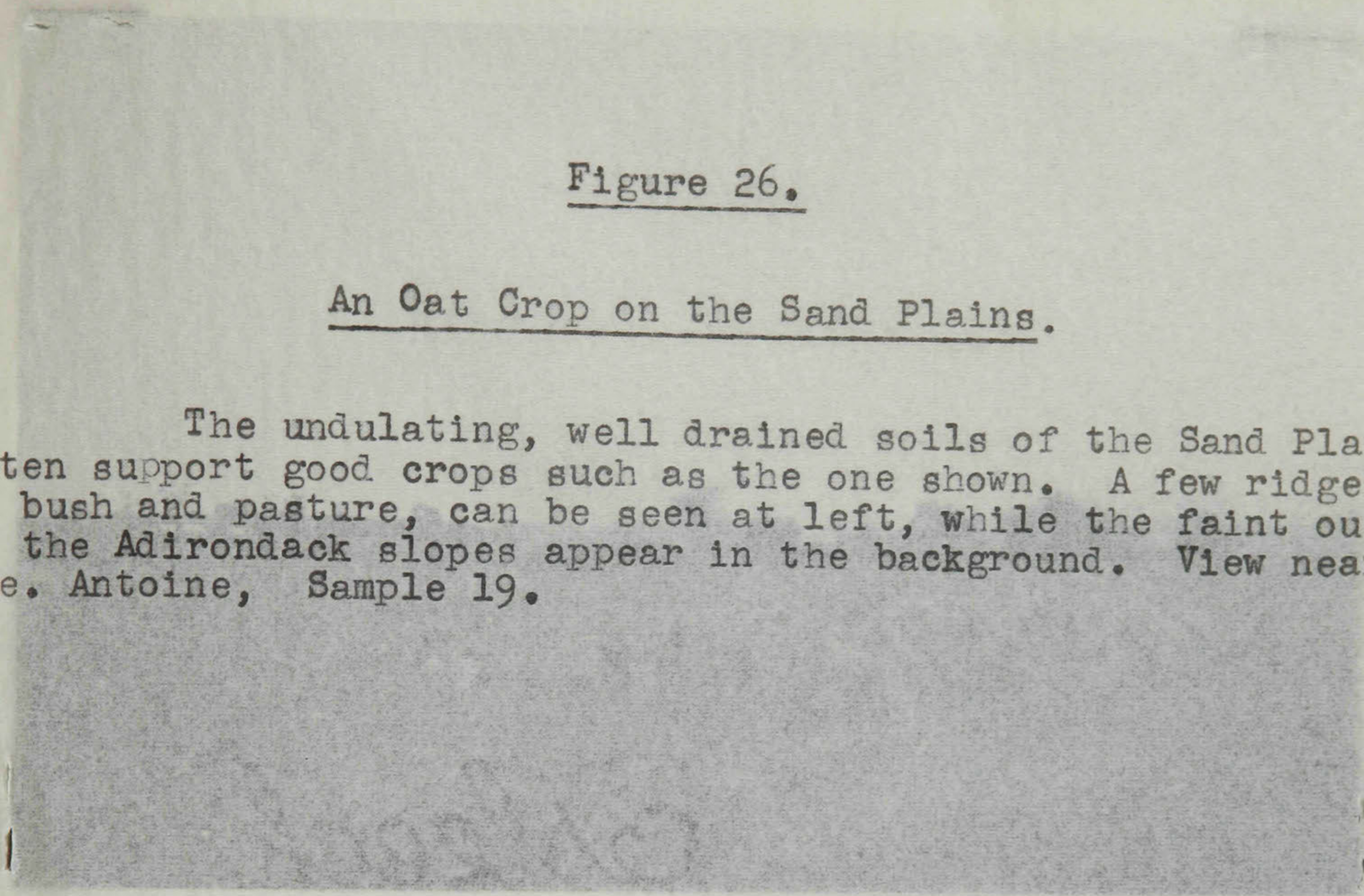


Figure 26.

An Oat Crop on the Sand Plains.

The undulating, well drained soils of the Sand Plains often support good crops such as the one shown. A few ridges, in bush and pasture, can be seen at left, while the faint outlines of the Adirondack slopes appear in the background. View near Ste. Antoine, Sample 19.

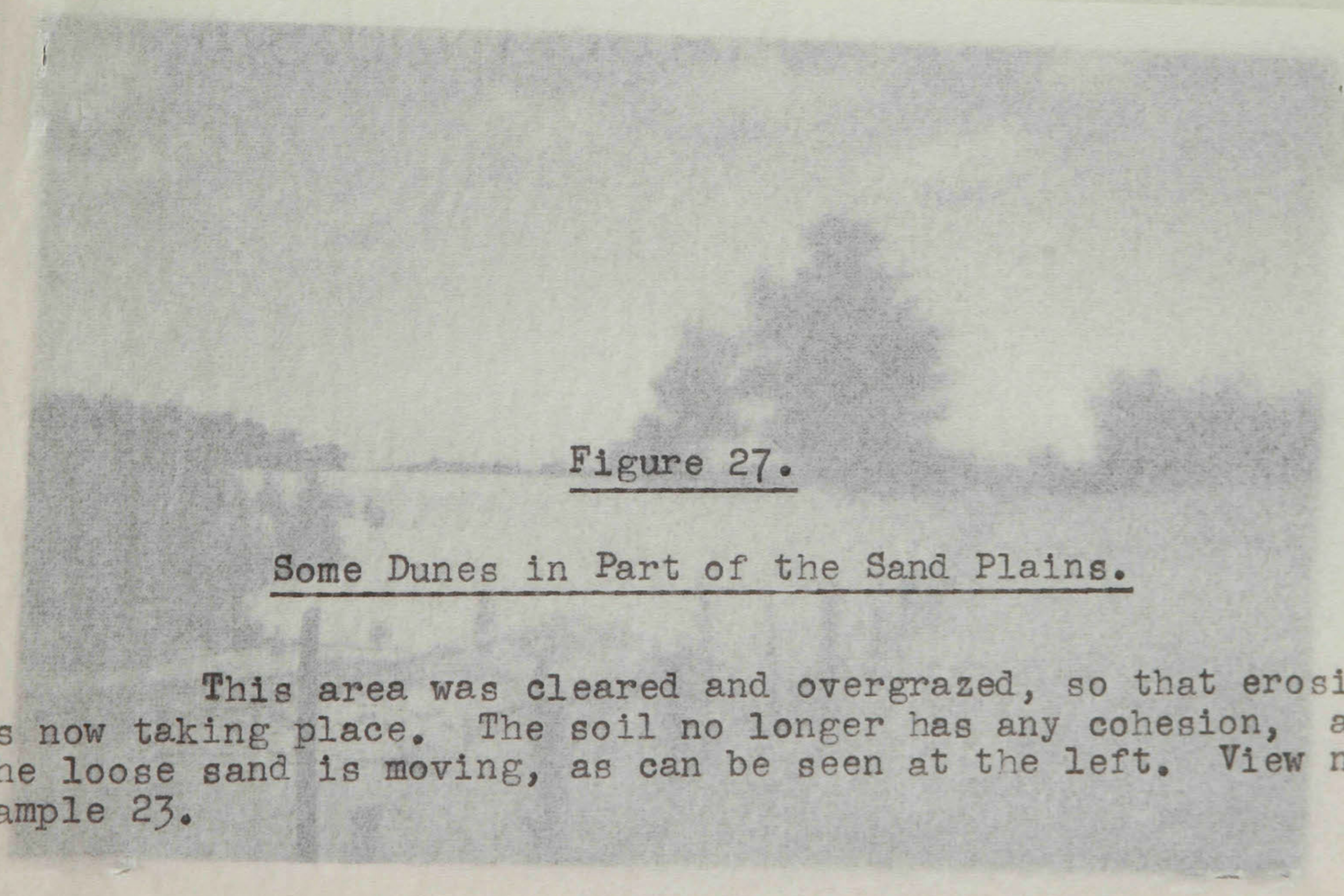


Figure 27.

Some Dunes in Part of the Sand Plains.

This area was cleared and overgrazed, so that erosion is now taking place. The soil no longer has any cohesion, and the loose sand is moving, as can be seen at the left. View near Sample 23.

both sides of the Chateauguay river. They are monotonously flat, and the level stretches of clay and clay loam soils are only occasionally broken by short steep gullies leading to the entrenched narrow floodplains of the larger rivers.

Except for the steep river banks, gullies, and grassy floodplains, the land type is fully cultivated. The fields are geometrically shaped, and are sown to a large proportion of field crops. Dairy farming dominates the area, with some specialized vegetable production for canning or seed. From the ground, the plains appear more heavily wooded than they actually are, for the numerous graceful elms along the fence lines and riverbanks offer a sharp contrast to the monotonous succession of cultivated fields. The main land problems in the area are due to impeded drainage, and deterioration of soil structure under poor cultivation practices.

Clay and Ridge Plains. Upstream along the Chateauguay River and its tributaries, the clay plains gradually give way to clay and ridge plains. Here, small isolated ridges or hillocks of rough and bouldery moraine become quite frequent, and may form up to 20 percent of the land surface. The plains, although sometimes quite flat, are more often gently rolling; the steep gullies and entrenched floodplains of the previous land type are rare in this one.

Land use is much the same as on the clay plains. Only the clays are cultivated, while the hillocks serve as farmstead sites or are left in woodlot. In rare instances, the ridges are cleared and used as rough pasture, but whether cleared or not they are nearly everywhere used for grazing purposes. The most highly specialized dairy farms of the area, as well as nearly all of the farms specializing in purebred cattle breeding, are located on these clay and ridge plains.

Ridge and Vale Lands. Long stretches of ridge and vale lands occur in widely separated parts of the area. Here, the flat and easily cultivated terrain types are much restricted in extent, being in about equal dominance with marked moraine ridges. The pattern of cultivated fields conforms with the pattern of terrain types, and improved pasture land now virtually disappears. The cattle are pastured instead on the boulder ridges, while the limited areas of flat land are reserved for grains and hay. In a few places, the boulders have been cleared from small parts of the ridges to make additional cultivated fields.

The prosperity of adjoining farms often differs remarkably. Prosperity seems to depend on the varying proportion of flat plowable land and rough ridge land which is enclosed by each farm's boundaries. The main activity is dairying, but the herds are small in size and the milk is most often sent to local creameries or cheese factories. An occasional farmer may specialize in poultry, sheep, or orchards.

Ridge and Bog Lands. The ridge and bog lands are a variant of the ridge and vale type. The difference between the two is essentially in the soils; in the vales, the soils ar or mucks, but in this case, very little clay occurs. The low flat areas have either muck soils or peaty soils which are too poorly drained for cultivation. Land use is similar to that in the ridge and vale type, but due to the greater restriction of easily cultivated land, the prosperity of the farms is less.

Ridge Lands. Two broad bands of ridge land extend northeast-southwest in the area, and here are found some of the poorest agricultural conditions. Whereas the farmers even in the ridge and vale lands were able to leave the difficult terrain in an unimproved state, in the ridge lands there is no flat plowable soil. All cultivated fields have been laboriously made by clearing away the stones and boulders. Wide stone fences border the small, irregularly shaped and rolling fields of the ridge lands, and much of the area remains in overgrazed bush or rough pasture.

This land is not highly productive, and signs of abandonment are seen in old fields now growing up in scrubby wire birches or cedars. Farms are decidedly not prosperous, but are in fact often of a subsistence type where a meager living is eked out with the help of a few cows, pigs, chickens, and whatever income can be obtained from the woodlot.

Bedrock Slopes. On the upper part of the Adirondack slopes, land use conditions are much the same as on the ridge lands. The physical conditions differ, however: the terrain slopes gently or strongly, and the soils are only a shallow mantle of gravelly loam over the sandstones. Rocks and boulders have to be cleared from the fields, and here, too, much of the land is in a semi-abandoned condition. Farm prosperity is above the subsistence level, but appears to be declining. The main cash crop is hay, and although some additional revenue comes from the woodlots, the forests have not recovered from the effects of overcutting and the damage done by one severe forest fire. The soils generally are suffering from sheet erosion wherever cultivation occurs.

Bog and Bedrock Lands. Barren and useless are the two adjectives most readily applicable to the bog and bedrock type, which is surprisingly extensive in the area. The bare, flat expanses of sandstone, with their patchy covering of birches, may stretch for miles. Bogs are intimately associated with the bedrock, occupying shallow depressions in the surface with a thick cover of trees or shrubs and mossy plants. Drainage is badly impeded.

Perhaps these lands were always in their present state, or perhaps, once forested, they lost their soils as a result of man's activities. In any case, these lands are now entirely unproductive except for wild berries or what little firewood can be cut from the scrub birches. It is unlikely that any measure could be taken which would rapidly improve their productivity. The lands are apparently under private ownership, but they are certainly not farmed.

Beach and Terrace Slopes. Between the upper level bedrock slopes of the Adirondacks, and the sand plains at their base, lie the beach and terrace slopes. The land is step-like in character, a series of boulder-beach "risers" alternating with gently sloping gravelly or stony "treads". The beaches cannot be traced for long distances, but in most areas at least one beach can be found for every 15 or 20 feet of difference in elevation.

Stone fences are characteristic of the area, and the soils in many places are well adapted to apple growing, the special farming activity in the land type.

<u>Sand Plains</u>. The sand plains are the land type which varies most widely from a land use point of view, and their physical aspect also varies considerably from place to place. This variation suggests that the sand plains are rather unsatisfactory as a type; nevertheless, they are quite distinct from the other land types of the area. In every case the predominant soil material is sand, but the soil itself varies from half bog types through well-drained sandy loams to loose, moving sand dunes. The terrain is in general gently rolling and free from stones, although gravel is common.

Where the soil is loamy and not excessively drained (as, for instance, near St. Antoine), the land is quite productive; where soil drainage is impeded, the land is usually occupied by wet, swampy, bush and forest. In still other places, particularly in Dundee Township, excessive drainage and improper land use have caused the development of areas of loose sand dunes.

Bogs. Except for the stretch of bog along the shore of the St. Lawrence River, most of the other bogs of the area are being developed for more intensive agricultural use through artificial drainage. Some progress has been made in all areas, but it is only in the Ste.Clothilde district that agriculture is assuming any importance.

The flat-lying muck soils are adapted to vegetable growing, potatoes being the chief crop in the district mentioned. Elsewhere, the bogs are in much their natural state, although in some the edges have been cleared to make pasture land or hay meadow.

Summary. By combining the sampling study with the soil survey maps, it has been possible to draw a map of land types in the area, and for each type, to describe in general terms its physical and land-use aspects. This forms in itself a valuable contribution to land use analysis, but the map is also extremely useful, if not essential, in drawing of quantitative maps of land use. This special employment of the land-types map is described in the following sections of the chapter.

III. ISOPLETH MAPS OF LAND USE.

When the map test of accuracy was described in Chapter VIII, it was shown that a physically based map is superior to a map based on quantitative data alone. In this section, the method of drawing physically based maps is described, and some additional examples to those given in the preceding chapter are presented.[1]

To draw a physically based isopleth map, it is necessary to have at hand the quantitative data, the traverse observations, and the land types map. Since land use conditions in any one land type are fairly uniform, most isopleths should be placed near the boundaries between land types, as it is here that the most rapid changes in intensity of land use occur. Where, however, there is a change in land use intensity within one single land type, the isopleth concerned can logically be placed on the assumption that the change is gradual and uniform.

This means, in effect, that the concept of the hexagonally shaped sampled area must be rejected for drawing maps of the area as a whole. Instead, the sample data are assumed to be representative of the land types in which they occur, and the isopleths must be placed accordingly. However, where variations in land use intensity occur within one land type, the hexagonal concept should be retained as a basis for placing the isopleths. As a final step, the position of all isopleths should be checked by reference to the traverse observations.

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(1) The methods of drawing both isopleth and dot maps on the basis of quantitative data alone are well enough known, and need not be discussed here. A full description is given by Erwin Raisz, General Cartography, p. 243 ff. See also Wellington D. Jones, "Ratios and Isopleth Maps in Regional Investigation of Agricultural Land Occupance". Annals Assn. Am. Geog., 20: 177-195, 1930.

This technique can be used for almost any land use or ratio of which an isopleth map is desired. Figures 28 and 29 show hay and oats as a percentage of all field crops: they should be compared with the land types map, Figure 17, and also with the maps drawn from census data, Figure 11. The latter map gives a far more generalized picture than do the maps drawn from the sampling results. In addition, the relation of hay and oats intensity to underlying physical conditions is clearly brought out by the physically-based maps, whereas this relationship cannot be understood on the basis of the census maps. The same comparisons can be made between the map of improved land, Figure 30, and the comparable statistical map, Figure 10.

IV. DOT MAPS OF LAND USE.

Two types of dot maps may be drawn from the sample data; one kind on a physical basis, the other with no reference to physical conditions. Dot maps are useful for showing land uses that have not been very accurately sampled, or have a great variation from one point to another. Isopleths, if employed to show the distribution of such uses, tend to give an impression of accuracy which may be entirely unwarranted; furthermore, large variations require the use of too many isopleths, making the map appear crowded and confusing. Dots can, of course, be used to show major land uses, but the variation in these cases is not as well brought out by dots as it is by isopleths. Dots can be used to show only absolute quantities, and not ratios or intensities; isopleths

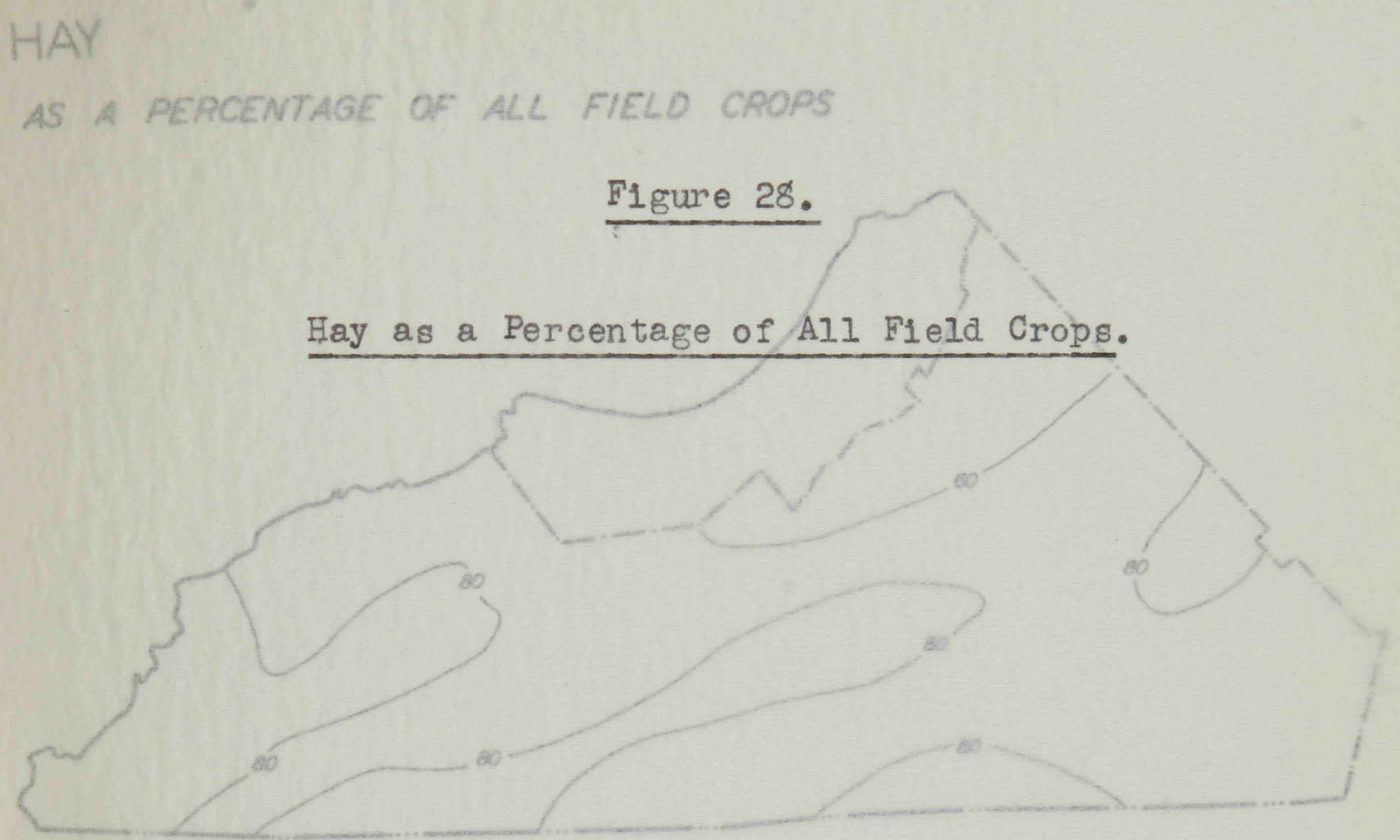


Figure 28.

Hay as a Percentage of All Field Crops.

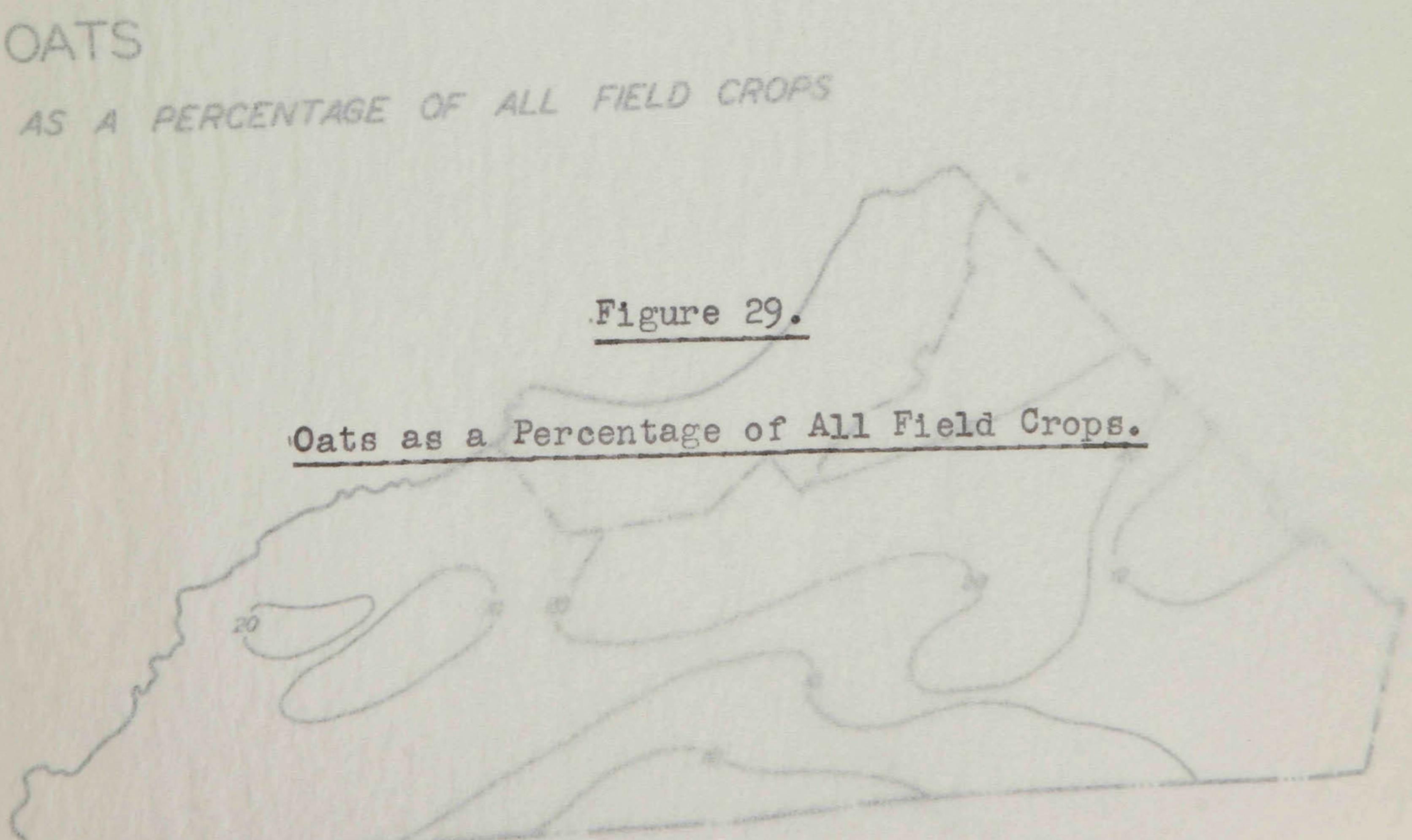
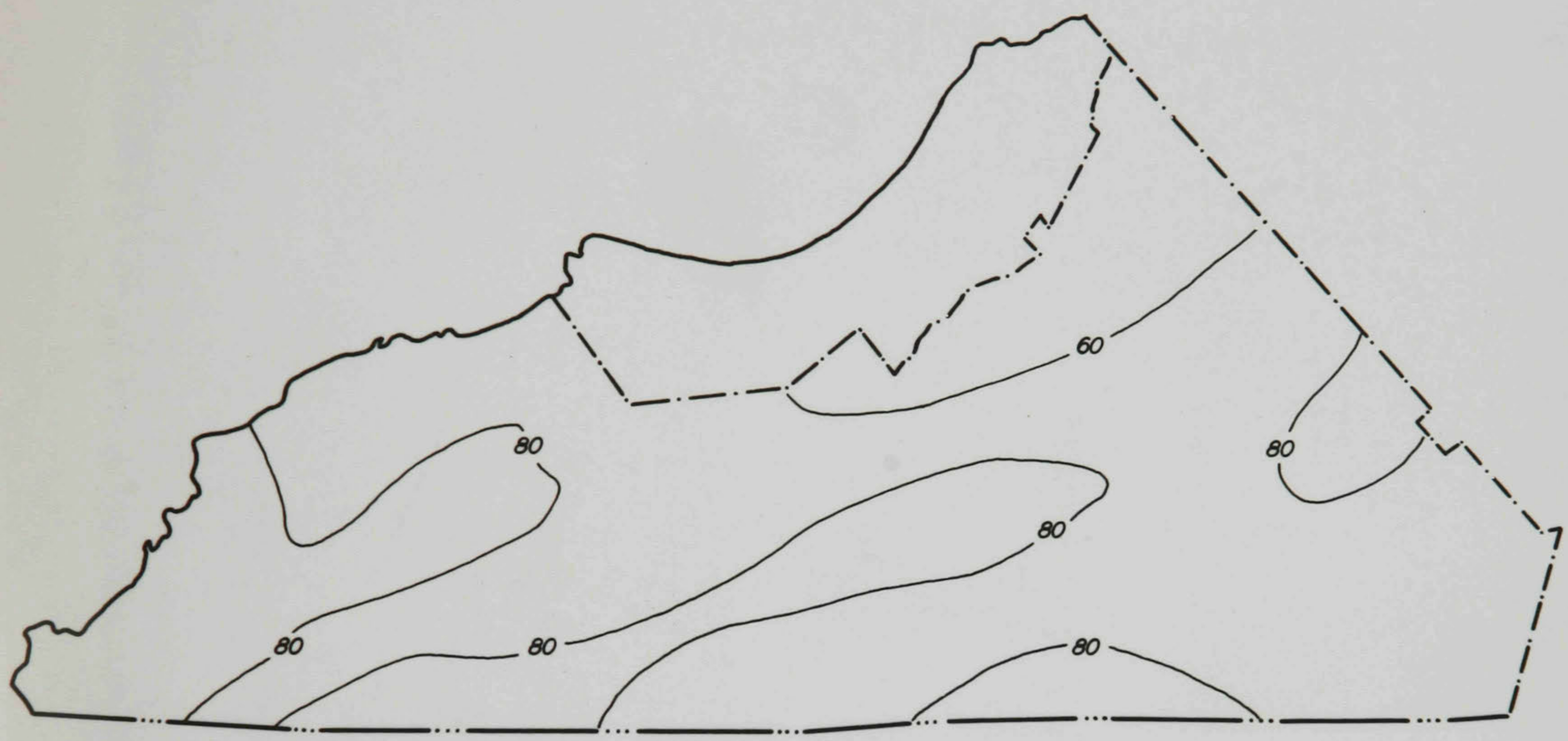


Figure 29.

Oats as a Percentage of All Field Crops.

HAY

AS A PERCENTAGE OF ALL FIELD CROPS



OATS

AS A PERCENTAGE OF ALL FIELD CROPS

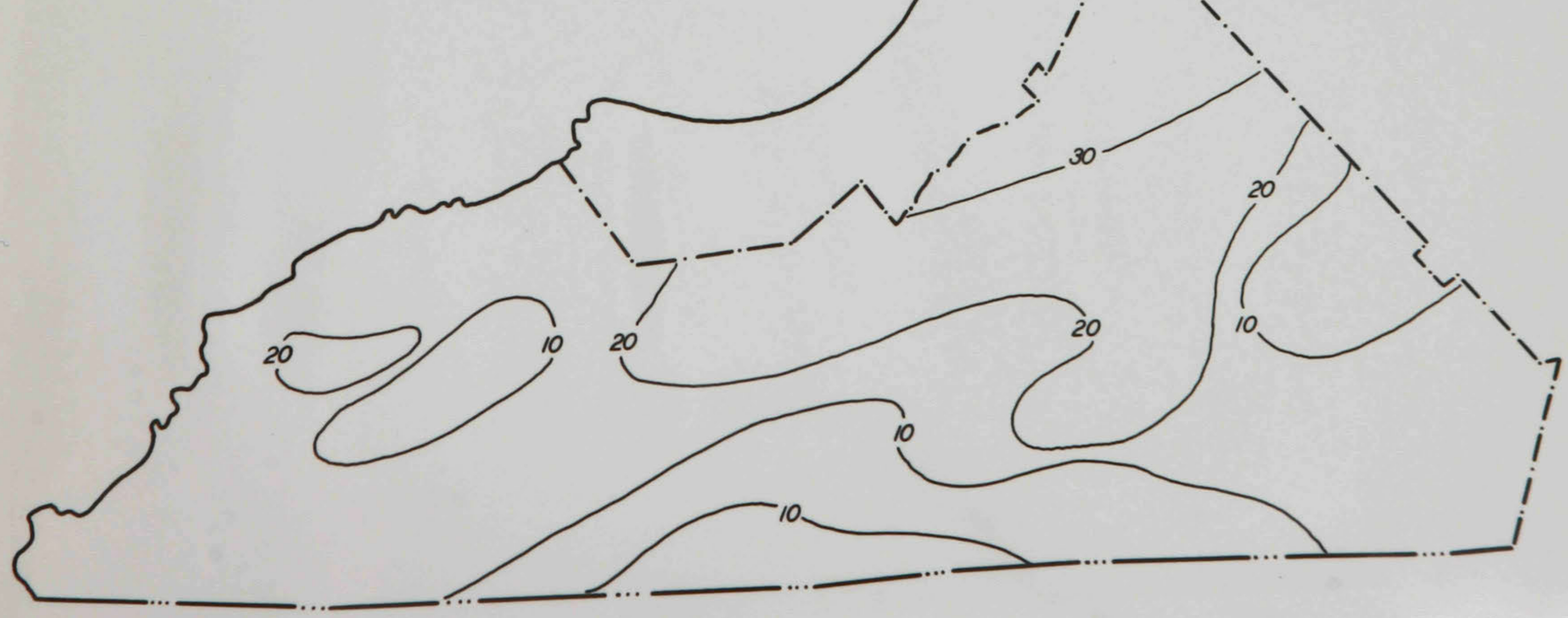
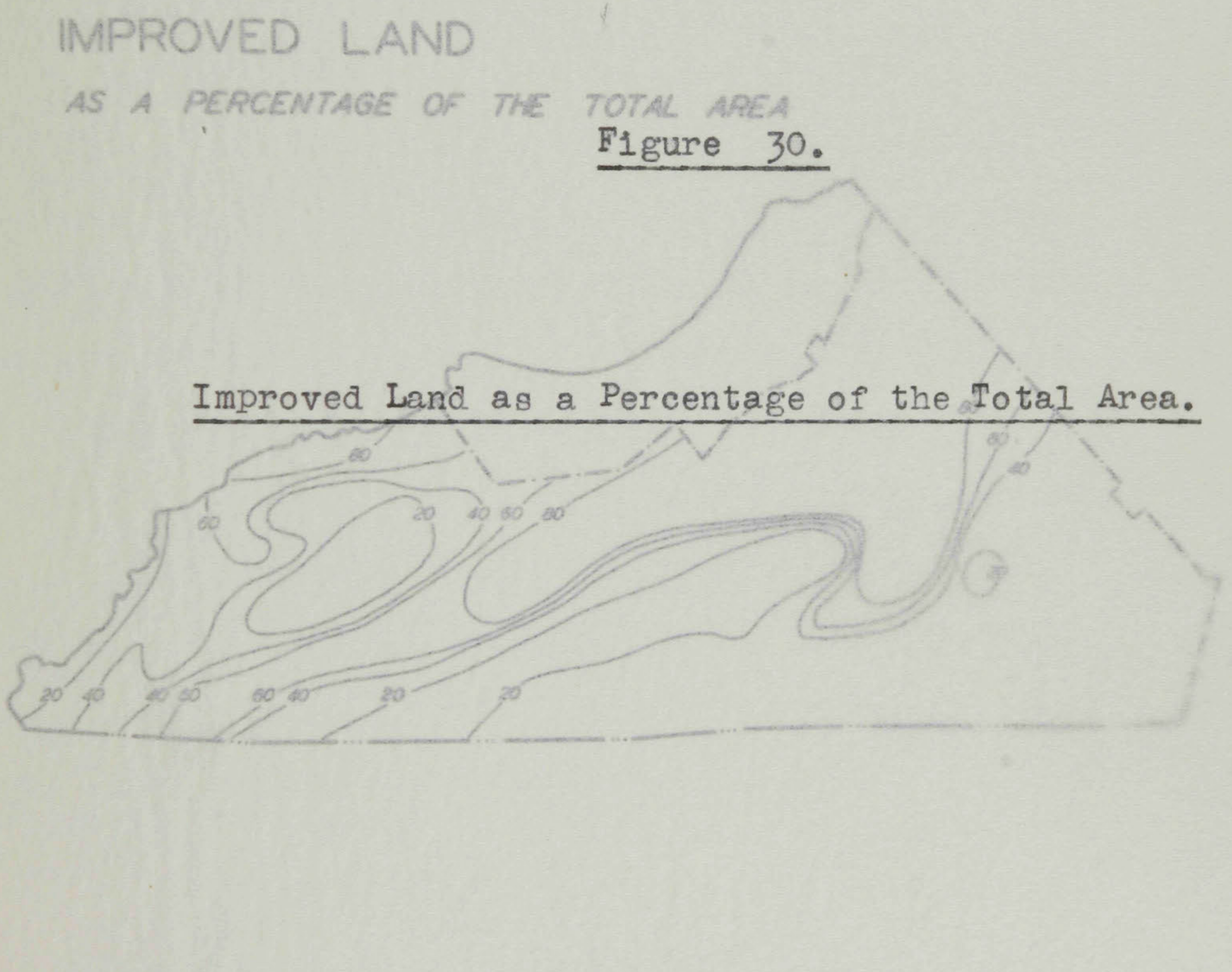


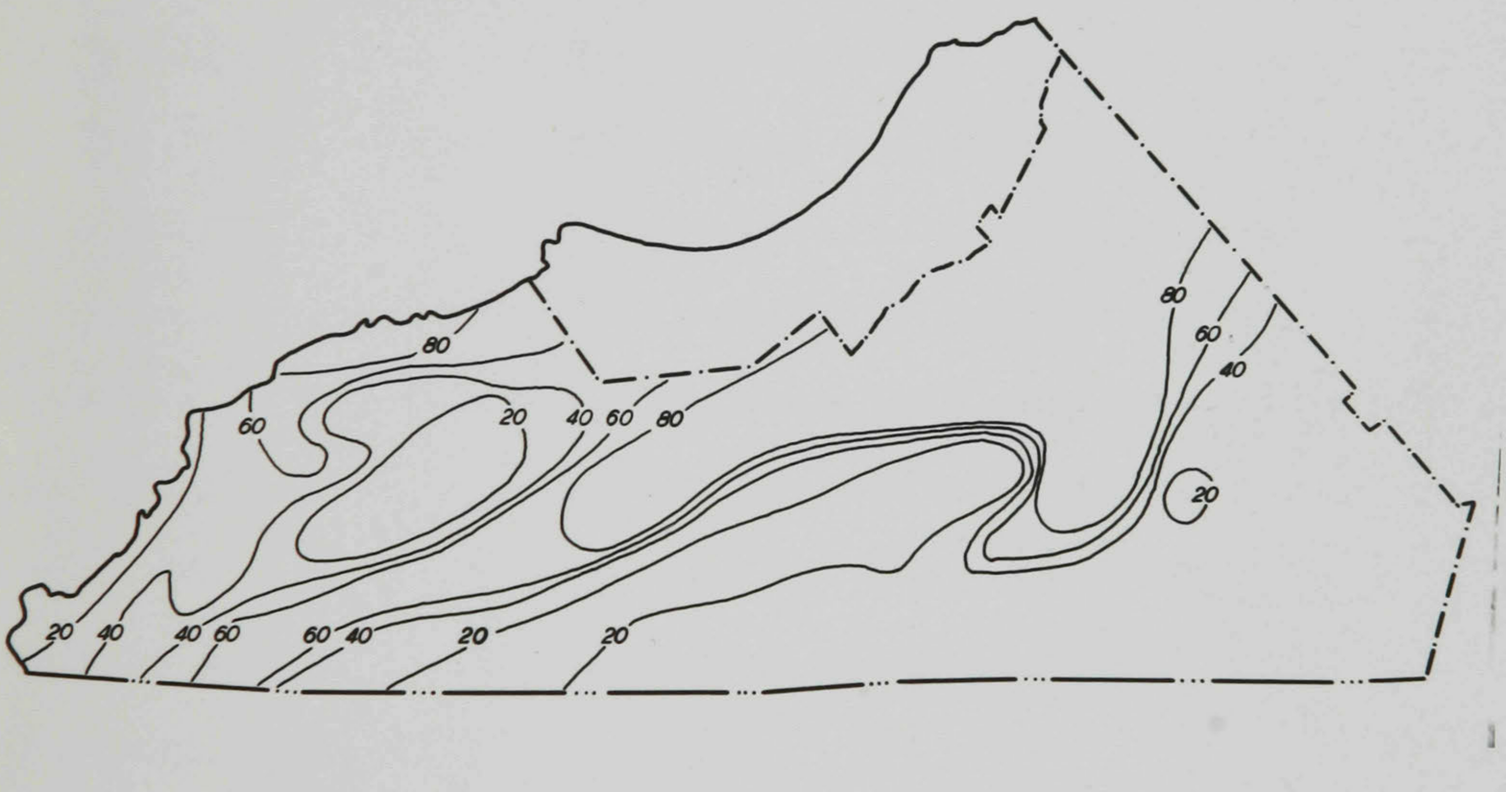
Figure 30.



Improved Land as a Percentage of the Total Area.

IMPROVED LAND

AS A PERCENTAGE OF THE TOTAL AREA



can show only the latter, and not absolute quantities.

Methods of Drawing the Dot Maps. To draw dot maps, the sample data must be converted from percentages to acreage figures, and such a figure obtained for the acreage of the particular use concerned in each sample and in each sampled area. Since the sizes of both samples and sampled areas are known the acreages are easily calculated.

For dot maps based on quantitative data alone, the hexagonal sampled area is used as the unit within which the dots are placed. This was done for the map of corn acreage, shown in Figure 31. Having calculated the number of acres in each hexagon occupied by this use (assuming the sample percentage to be a true sample of the hexagon) an equivalent number of dots were evenly distributed throughout the sampled area. The resulting map is rather approximate and inaccurate because of the probable error of sampling and because the dots were placed without reference to the physical conditions which limit the distribution of the crop.

It is possible to draw a better dot map by having regard to physical conditions. In this case, the concept of the hexagonal sampled area must once again be partly discarded. Instead, each sample is regarded as being representative of its land type. Each land type is then divided into units of the same area as each sample block, and in each unit a number of dots, equivalent to the acreage of the particular use in the sample block are uniformly distributed.

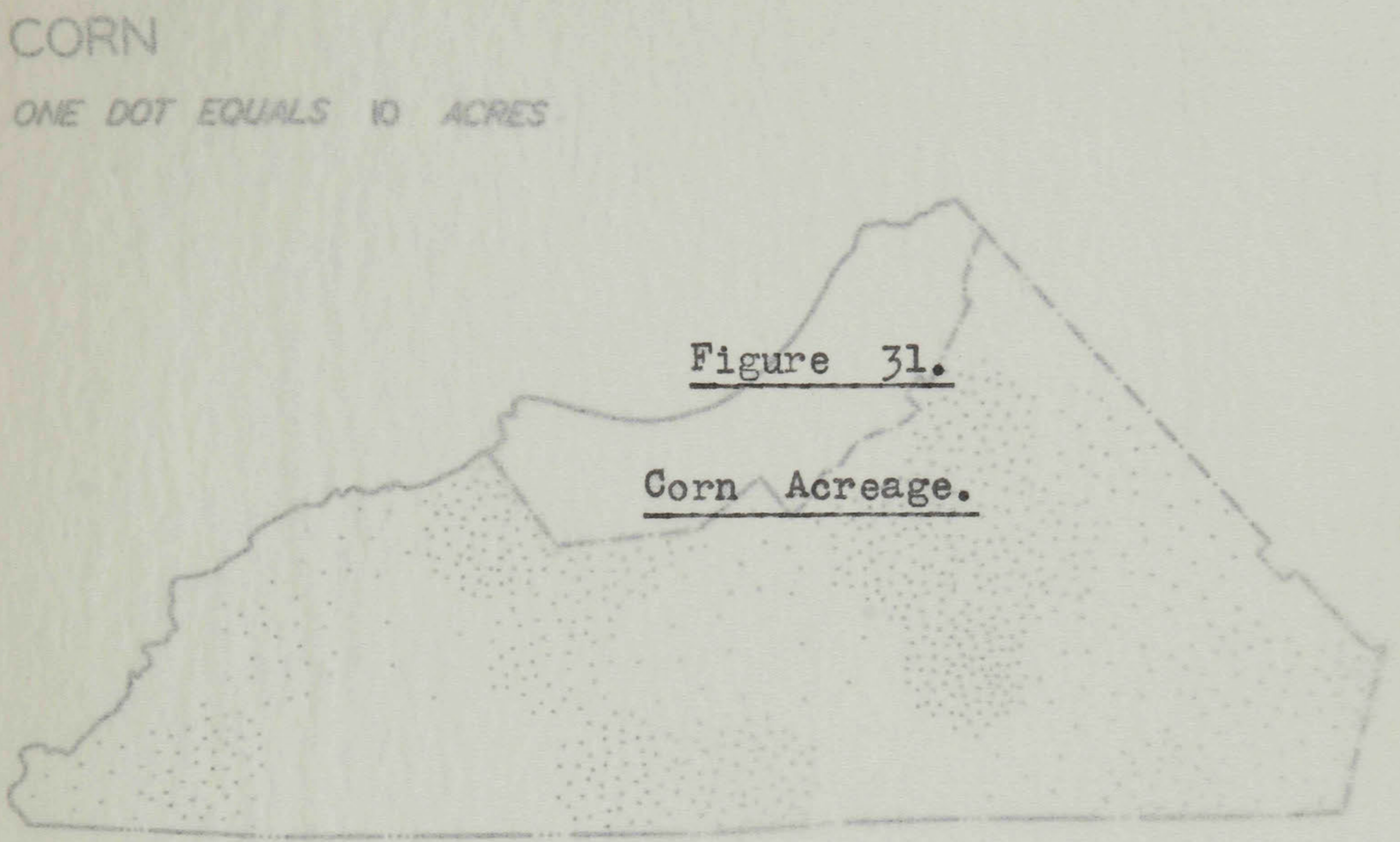


Figure 31.

Corn Acreage.

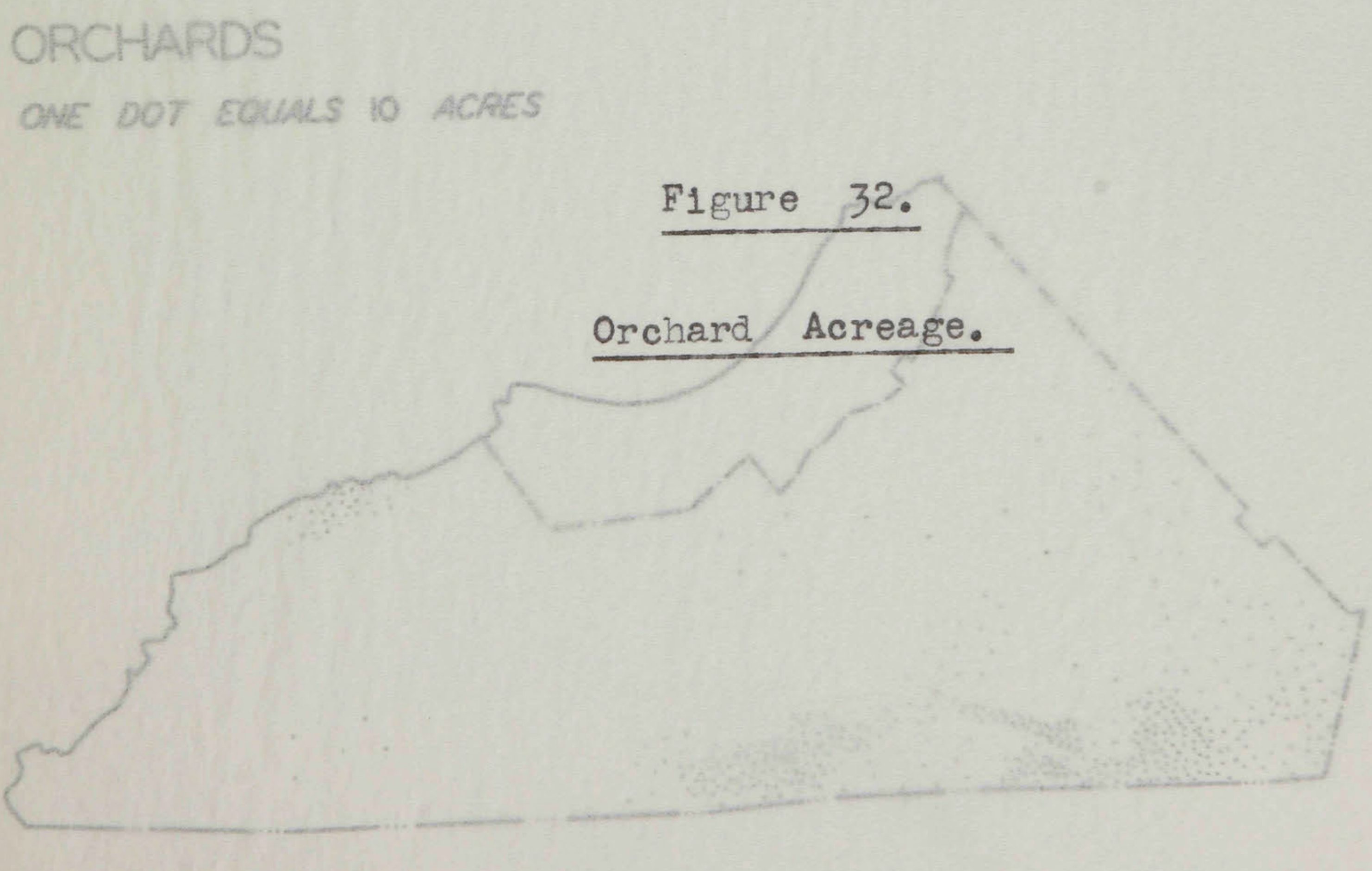
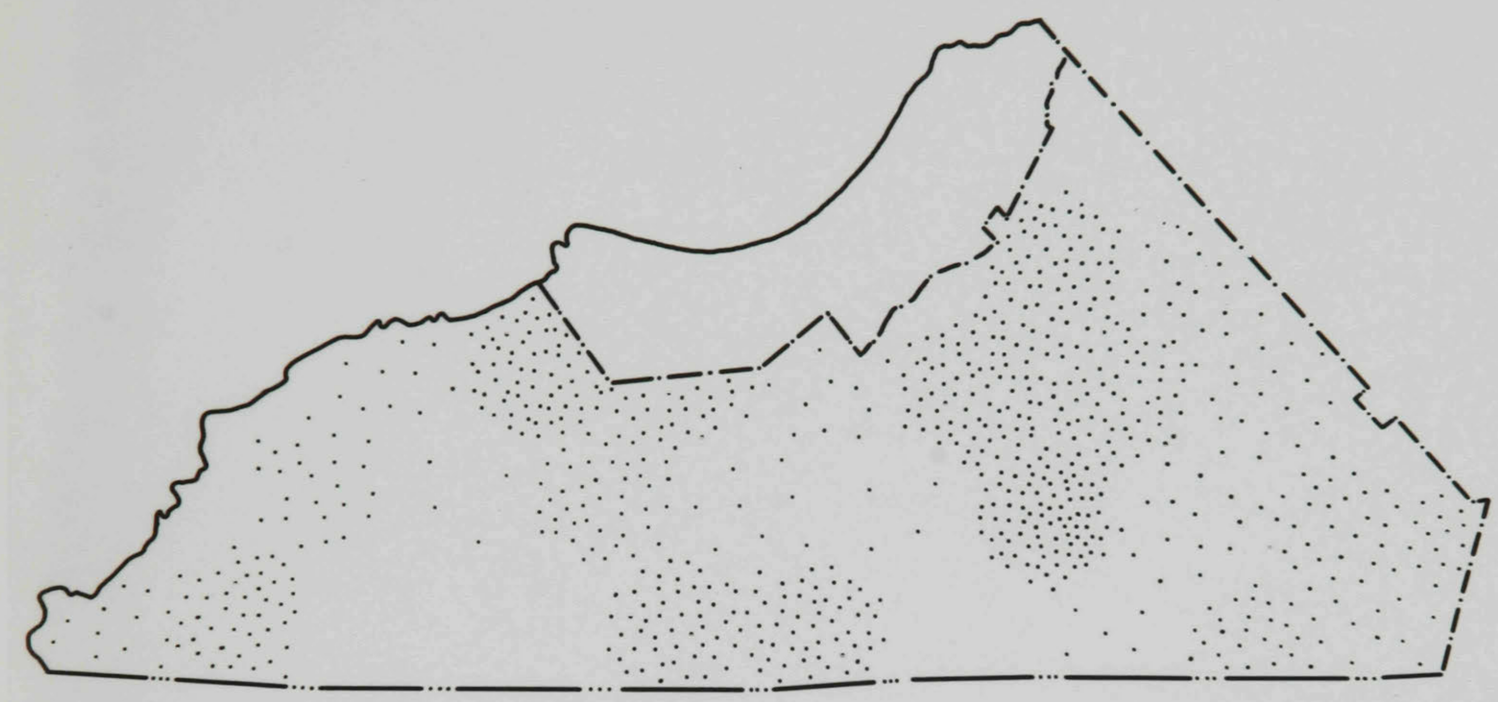


Figure 32.

Orchard Acreage.

CORN

ONE DOT EQUALS 10 ACRES



ORCHARDS

ONE DOT EQUALS 10 ACRES

Where more than one sample occurs within a single land type, the change in the number of dots per unit area is made at the boundary between hexagons. The map of orchard acreage, Figure 32, was drawn in this manner. This type of map represents well the distribution and average density of the land use concerned, but because of the many assumptions involved in the calculations, it would be unwise to take quantitative data from the map by counting dots. The dots can be considered only approximately equivalent to the actual number of acres of the use concerned.

V. LAND USE PATTERNS.

Land use patterns are well revealed by the mapped samples themselves. Four patterns typical of various parts of the area are reproduced in Figures 33 to 36. The patterns shown are not the only ones to be found in the area, but the reproductions and accompanying comments are sufficient to indicate the way in which the samples can be used to bring out variations in land use patterns.

VI. CONCLUSIONS

The techniques described in this chapter can be used to draw analytical maps of land use and land use relationships which, in combination with a study of physical conditions and land use patterns, may form the basis of a complete land use analysis.

Only a few of the maps that it is possible to draw have

Figure 33.

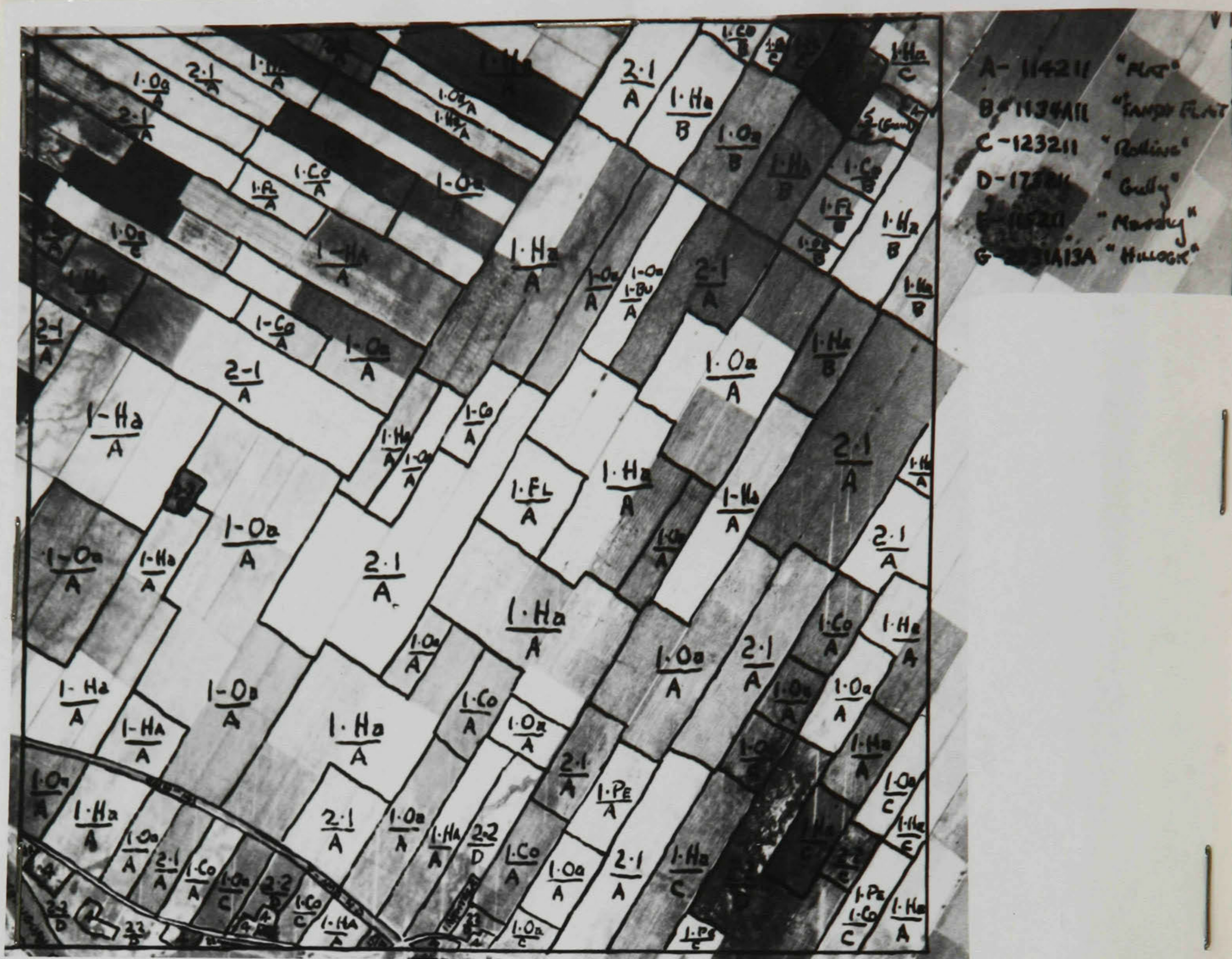
A Land Use Pattern on the Clay Plains.

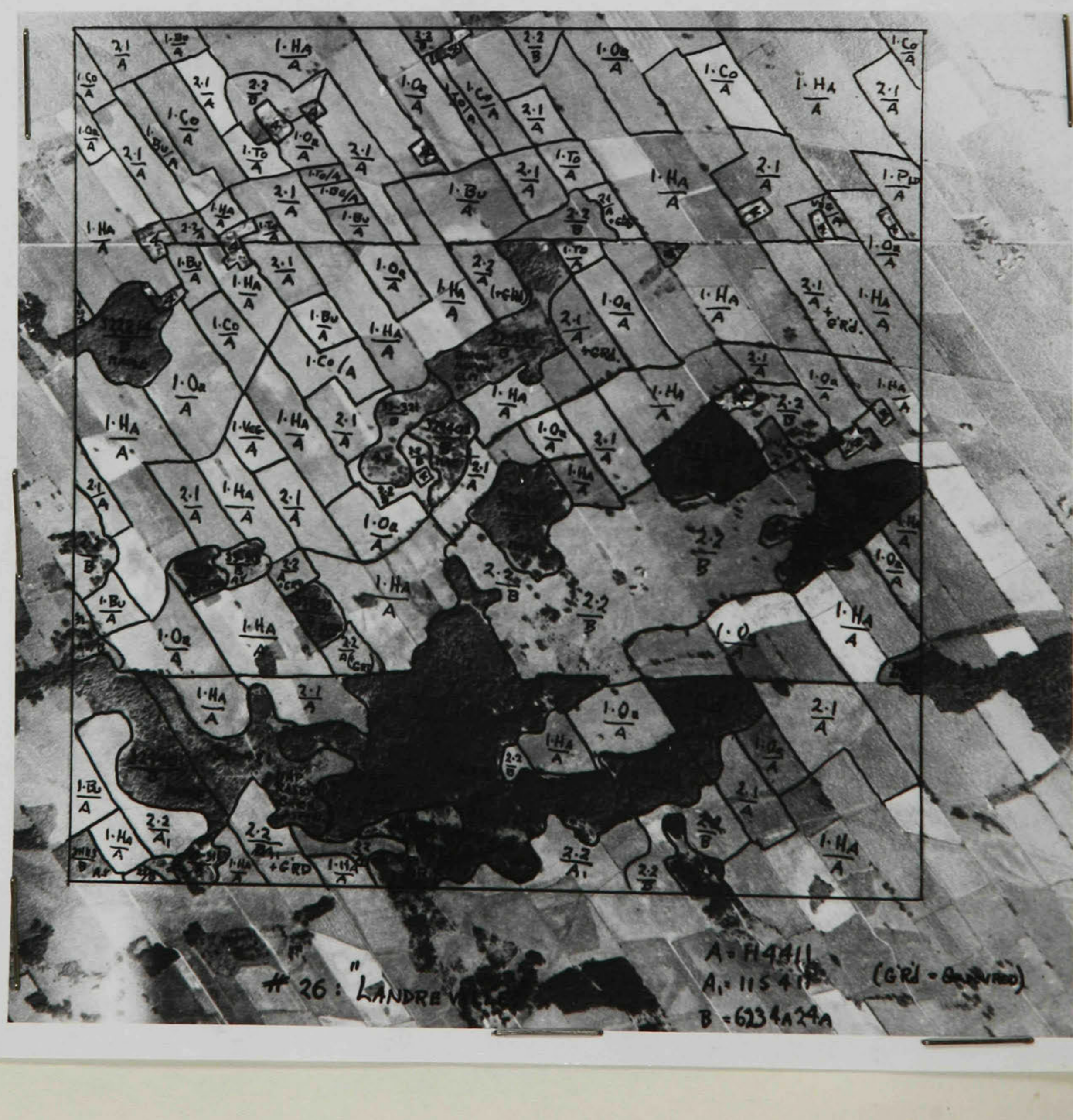
This reproduction of sample 40 shows the rectangular field pattern typical of the clay plains. The fields themselves are smaller than the unit parcels delimited on the photograph (like fields were joined for convenience in measuring their areas) and are of a rather uniform size and shape. The pattern is characterized by large acreages of grain and fodder crops and an almost complete absence of woodlot. In areas such as this, the physical quality of the land is so uniform that the farmer is at liberty to use his fields in almost any way he desires.

Figure 34.

A Land Use Pattern on the Clay and Ridge Plains.

In sample 28, moraine ridge is an important terrain type. Since this land cannot be easily cultivated, the farmer makes an adjustment by reducing the amount of rotation pasture and clearing some of the ridge for rough grazing. The contrast between the irregular shape of the unit parcels on B terrain types (ridge) with the geometrical fields of the A type (clays) should be noted.


A- 114211 "FLAT"
B- 1134A11 "SANDY FLAT"
C-123211 "Rolling"
D-173811 "Gully"
"Marshy"
"Hillock"


# 26: "LANDRE V
A=114411
A1 115411
B =6234A24A
(G'Rd = Grassland)

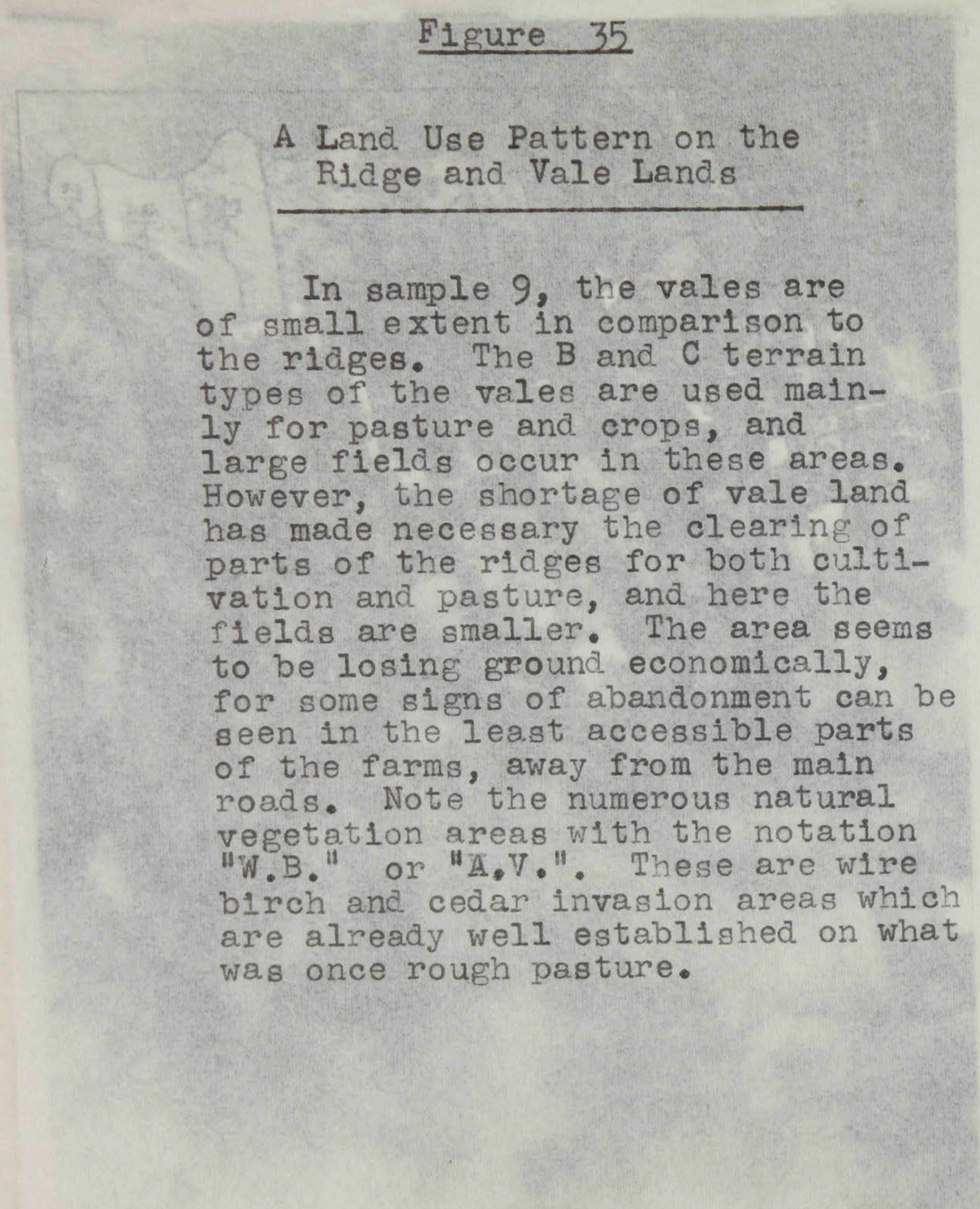


Figure 35

A Land Use Pattern on the Ridge and Vale Lands

In sample 9, the vales are of small extent in comparison to the ridges. The B and C terrain types of the vales are used mainly for pasture and crops, and large fields occur in these areas. However, the shortage of vale land has made necessary the clearing of parts of the ridges for both cultivation and pasture, and here the fields are smaller. The area seems to be losing ground economically, for some signs of abandonment can be seen seen in the least accessible parts of the farms, away from the main roads. Note the numerous natural vegetation areas with the notation "W.B." or "A.V.". These are wire birch and cedar invasion areas which are already well established on what was once rough pasture.

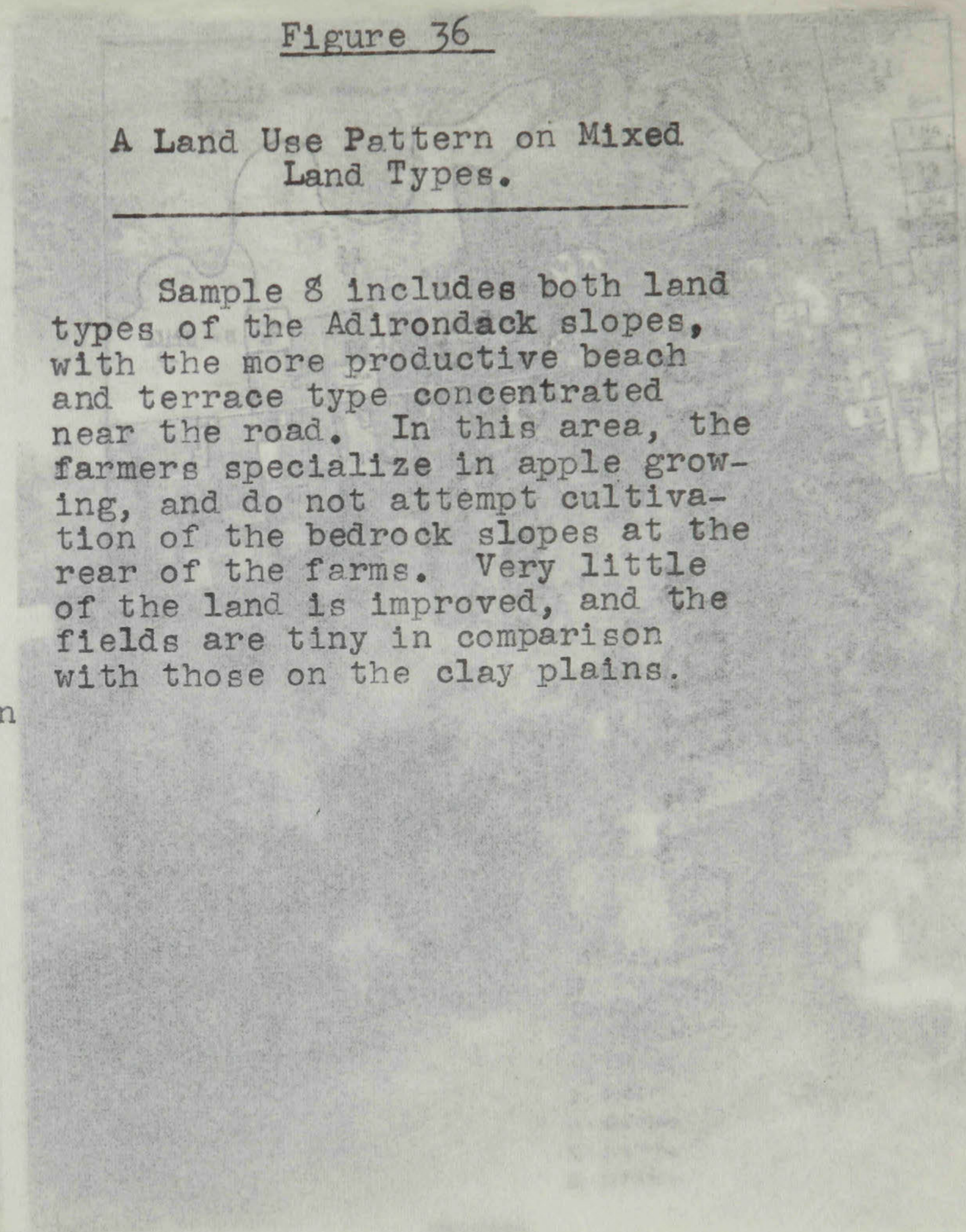


Figure 36

A Land Use Pattern on Mixed Land Types.

Sample 8 includes both land types of the Adirondack slopes, with the more productive beach and terrace type concentrated near the road. In this area, the farmers specialize in apple growing, and do not attempt cultivation of the bedrock slopes at the rear of the farms. Very little of the land is improved, and the fields are tiny in comparison with those on the clay plains.


#9 - "Robson Brook"
A = 6331A23
A1 = 6331A24
A2 = 6431A22
"Moraines or Beaco"
B = 314622
B2 = 315621
"Bogs"
C = 424412
"Bottoms"


#8 - "Covey Hill"
A = 523723
B = 543734A
C = 513522
C1 = 543522
C2 = 553522
D = 415111
E = 515734A
G1 = 533714A
G2 = 553714A

been presented here, since the purpose is not to present a complete land use analysis nor even to describe the lines that such an analysis should take. The method of analysis is quite independent of the method of survey; hence, the purpose of this thesis has been fulfilled by indicating the ways in which the sampling data may be used in analysis.

Although any series of maps drawn for analytical purposes would have to be drawn according to one or the other of the techniques described, it should be noted that the maps which have been used to illustrate the different techniques do not begin to exhaust the possibilities of the sampling data.

Maps could be drawn from the sample data to illustrate, for example, the distribution of ill-drained land, erosion conditions, and the degree of stoniness or depth of the soil. Maps could be drawn for each land use which was sufficiently accurately sampled. In addition, many important ratios could be expressed in map form, as, for example, the ratio of the amount of rough pasture to the amount of easily cultivated land. A comparison and discussion of these maps could easily lead to an analysis of the area in terms of land use regions; and any survey method which produces this possibility must be considered to have fulfilled its purpose.

Chapter X.

CONCLUSIONS: THE VALUE OF THE HEXAGONAL SAMPLING SYSTEM

This final chapter presents a general synthesis of the separate phases of the investigation,in order to show the hexagonal sampling system's range of applicability within the general field of intermediate land use survey.

Whether or not the system will be useful in any particular survey will have to be decided by the surveyor, who will want to know the practical advantages to be gained, the kind of results obtainable, and their probable accuracy. He will also want to make sure that the system is suitable for studying the kind of area to be surveyed. In this chapter, the advantages and limitations of the hexagonal sampling system are discussed from each of these points of view. At the same time, suggestions are made concerning additional investigations which might improve the usefulness of the system.

I. THE PRACTICAL ADVANTAGES OF THE SYSTEM: TIME-SAVING CHARACTERISTICS.

The need to cover large areas at a faster rate than detailed methods permit is one of the main reasons for the development of intermediate survey methods. The hexagonal sampling system, as applied in the test area, provided a rapid rate of coverage: twenty square miles per working day, for one surveyor.

This rate is eight times that of the detailed survey of Great Britain, but is somewhat less than half the rate achieved with the unit-area method in the Tennessee Valley. However, the flexibility of the hexagonal system provides quite a variation in the possible rates of coverage.

In general, the rate will vary inversely as the percent detailed coverage. If an area could be adequately studied with only 5 percent coverage, the rate would be about forty square miles per day per survey team. With 20 percent coverage the rate would be reduced to about ten square miles.

For any given percent coverage, the actual rate may be affected by the grid dimensions employed. A faster rate would probably be achieved by using large samples, rather than by using small samples in greater number. What the actual difference in rates would be can only be determined by further studies, because only one set of grid dimensions was used in the course of this investigation.

The rate may also be affected by the kind of data required by the objectives of the survey. If, for instance, the survey requires only a broad classification of land use -- cultivation, pasture, woodland, and waste -- then the survey of each sample can be made quite rapidly. On the other hand, the employment of a very detailed land use classification calls for a slow and painstaking study of each sample. It must also be considered that an accurate sampling of broad land use classes will be achieved with fewer samples than are required for an accurate sampling of detailed land use classes.

Finally, the rate will vary in different areas. In open country with an abundance of good observation points, a larger expanse of land can be mapped in a shorter time than is possible in close, heavily wooded country.

All of the above considerations apply just as much to a square pattern of samples as they do to an hexagonal pattern. For any given sample spacing and size, the square pattern requires a smaller percent coverage than does the hexagonal pattern. Therefore, some advantage is to be gained by using a square pattern: however, it should be remembered that the hexagonal pattern gives the more even distribution of samples.

II. THE KIND OF RESULTS OBTAINABLE AND THEIR PROBABLE ACCURACY.

The Kind of Results Obtainable. In the test area, the use of the hexagonal sampling system resulted in both qualitative and quantitative maps of land use, and it was concluded that an analysis of land use could be made from the data provided. Although the accuracy of both the data and the maps varied according to the amount and distribution of each particular use, a high index of accuracy was shown for those uses which are of major importance in the area. The maps represent a great refinement over the statistical maps drawn from census data, a result which could not have been achieved by a rapid reconnaissance survey.

However, these results were achieved by relying on the detailed soil maps of the area.. The accuracy of the land use maps was shown to depend on the accuracy of the land types map; in the test area, this accuracy in turn depended on the use of the soil maps in conjunction with sample and traverse observations.

It might have been possible to draw an equally accurate map of land types on the basis of sample and traverse observations alone, but no attempt was made to do so in the course of this investigation. The possibility still remains; but if the hexagonal sampling system is to be as useful in areas where soil maps do not exist as it is in areas where they do, some additional studies should be made. An investigation of the techniques for making quantitative traverse observations, and of the comparative desirability of using road or line traverses between samples would provide further refinement to the system. Alternatively, the possibility of making land type maps through an interpretation of aerial photographs should be studied.

<u>The Probable Accuracy of the Results.</u> The accuracy that will be achieved in any particular survey cannot be completely forecast on the basis of this investigation alone. However, the results of the test application suggest that accuracy of the degree achieved in this investigation will be approached in any area -- provided that the dimensions of the grid employed are determined according to the land use and physical characteristics of the area.

However, the theory of the determination of grid dimensions, as presented in this thesis, should be more fully tested. To this end, further studies should be made of the proper sample size to use in different kinds of area, and of the results obtained by using different sizes of sample in the same area. An investigation of the relation of field size to sample size, comparable with Proudfoot's investigation of the correct length of traverse lines, would be most useful.[1] In this way, the probable accuracy of the results could be more completely forecast.

III. THE APPLICABILITY OF THE METHOD TO VARIOUS AREAS

Since the hexagonal sampling system is designed to give a faster rate of coverage than that provided by detailed methods, it should only be used when this purpose is served. In theory at least, it is possible to apply the method anywhere, but some kinds of area by their very nature require such a high percent coverage that no advantage is gained by employing samples. In practice, the method will only be useful in areas where the percent coverage can be kept low.

In any area, the necessary percent coverage is determined mainly by the average distance between land use boundaries (regulating sample spacing) and the homogeneity of land use patterns (regulating sample size). With these two factors in mind,

(1) Proudfoot, op. cit.

conclusions can be drawn regarding the applicability of the method to various areas.

<u>Area of Strong Relief</u>. In areas of strong relief, the use of the system is not recommended. Land use is certain to be sharply differentiated, according to changing topography, in mountain, dissected plateau, or ridge-and-valley regions. In the test area, this type of differentiation was found along the Adirondack slopes, but the system only worked satisfactorily there because the samples concerned happened to be advantageously located.

A far different result might have been obtained if the grid had been located in another position. A shift two miles to the north would have given no samples of the Adirondack slopes. To ensure an adequate sampling of these slopes, no matter what the location of the grid, the sample spacing would have had to be reduced to about 2.5 miles. This would have increased the coverage to over 30 percent, far more than necessary for the remainder of the test area.

For the above reasons it is concluded that the hexagonal system is not economical in areas where the relief plays an obvious role in differentiating land use. Where land use boundaries occur every two or three miles, it would be more appropriate to use some other method, such as traverses across the grain of the country.

<u>Rural Areas on the Periphery of Urban Centers.</u> Rural land uses surrounding a city or town are influenced by urban pressures of several kinds. Some of these tend to increase the intensity of agricultural use, while others may cause some lands to become idle. Land use changes in these areas are sharp, both in space and in time, so that in surveying these changes a method is needed which is sufficiently economical to permit frequent repetition.

However, the hexagonal sampling system is not adapted to this task. For example, some studies of Montreal indicate that the influence of the city is noticeable for a radius of several miles, with the most important land use changes occurring within one mile of the edge of the built-up area. Rural land use in this inner zone is not at all homogeneous, so that it becomes quite impossible to find a sample that will represent the area properly without, at the same time, giving too high a percent coverage.

The conclusion is that in urban-fringe areas of the type described, the hexagonal system cannot be used to advantage. If a detailed survey cannot be carried out, some system combining radial and concentric traverses might be adapted to the problem.

<u>Areas of Gentle Relief.</u> The hexagonal sampling system is best suited to areas of gentle relief, such as plains or lowlands. These areas have land use patterns and boundaries ranging from the broad and simple kind of the western wheatlands

to the more complicated kind found in the test area. Within such areas it is possible to adjust the sample size and spacing to give an economical percent coverage. Furthermore, the objective and quantitative character of the system is well suited to areas of gentle relief, in which land boundaries are often so broad as to be imperceptible to the eye.

IV. SUMMARY

The test application of the hexagonal sampling system has indicated that the method, if used in areas of suitable characteristics, is capable of producing results of greater refinement and precision than those possible with a reconnaissance survey. It has also been shown that the rate of survey is considerably higher than is possible by detailed methods, and that the rate compares favourably with that given by the unit-area method. A slight increase in rate is possible if square pattern sampling is used, but this is achieved at some sacrifice of evenness of sample distribution.

The method is well suited to the study of areas of gentle relief, but it is not satisfactory for urban-fringe studies or areas of strong relief. One drawback to the method is that it is more difficult to use when detailed soil maps are not available, but this disadvantage may possibly be overcome through further refinements of the traversing technique. For these reasons, the hexagonal sampling system shows promise of being capable of wide application in the field of intermediate land use survey.

BIBLIOGRAPHY

I. METHODOLOGY

Barnes, C.P., "Land Resource Inventory in Michigan," Economic Geography, 5: 22-55. 1929.

Barnes, J.A., and A.H. Robinson, "A New Method for the Representation of Dispersed Rural Population," Geographical Review, 30: 134-7, 1940.

Bercaw, Louise O., and Annie M. Hannay, Bibliography on Land Utilization, 1918-1936. U.S. Department of Agriculture Miscellaneous Publication No. 284, 1938. 1508 pp.

Black, John D., editor, Research in Agricultural Land Utilization -- Scope and Method. Social Science Research Council, Bulletin No. 2, 1931. 201 pp.

Blanchard, Raoul, Le Centre du Canada Francais -- Province de Québec. Montréal: Librairie Beauchemin, Ltée., 1947. 577 pp.

Buck, John Lossing, Land Utilization in China. 3 volumes. Volume II, Atlas. Nanking: The University of Nanking, 1937. (Published in the United States by the University of Chicago Press.) 146 pp.

Christians, William F., "The Line-Block Traverse -- An Experimental Field Technique," (Abstract), Annals of the Association of American Geographers, 32: 1942, p. 108.

Colby, Charles C., "Changing Currents of Geographic Thought in America," Annals of the Association of American Geographers, 26: 1-37, 1936.

Frankton, C., and L.C.Raymond, "An Ecological and Crop Survey of Stanstead County," Scientific Agriculture, 22: 178-194, 1941.

Goodsell, O.E., Land Classification: A Selected Bibliography. U.S. Department of Agriculture, Bureau of Agricultural Economics, Bibliography No. 83. Washington, 1940. 102 pp., (mimeographed).

Graham, Edward H., Natural Principles of Land Use. New York: Oxford University Press, 1944. 274 pp.

Hart, V.B., "Land Use in New York," Cornell University Extension Department, Bulletin No. 406, 1939. 18 pp.

Hartshorne, Richard, The Nature of Geography. (Published in its entirety in): Annals of the Association of American Geographers, 29: 171-658, 1939.

Hudson, G. Donald, "A Quantitative Approach to Land Use Problems," (Abstract) Annals of the Association of American Geographers, 25: 1935, p. 44.

_________, "The Unit Area Method of Land Classification," Annals of the Association of American Geographers, 26: 99-112, 1936.

_________, "Methods Employed by Geographers in Regional Surveys," Economic Geography, 12: 98-104, 1936.

Jacks, G.V., Land Classification for Land Use Planning. Imperial Bureau of Soil Science, Technical Bulletin No. 43, 1946. 73 pp.

Jones, Wellington D., "Ratio and Isopleth Maps in Regional Investigation of Agricultural Land Occupance," Annals of the Association of American Geographers, 20: 177-87, 1930.

_________, and Vernon C. Finch, "Detailed Field Mapping in the Study of the Economic Geography of an Agricultural Area," Annals of the Association of American Geographers, 15: 148-57, 1925.

Lee, Chun-fen, "Land Utilization in the Middle Grand River Valley of Western Ontario," Economic Geography, 20: 130-51, 1944.

Lewis, A.B., Methods Used in an Economic Study of Land Utilization in Tompkins County, New York, and in Other Similar Studies in New York. Cornell University Agricultural Experiment Station, Memoir No. 160, Ithaca, N.Y.: Published by the University, 1934. 57 pp.

Mackay, J.Ross, "Dotting the Dot Map," Surveying and Mapping, 9: 3-10, 1949.

McMurry, K.C., "Geographic Contributions to Land-Use Planning," Annals of the Association of American Geographers, 26: 91-8, 1936.

Proudfoot, Malcolm, "Sampling with Transverse Traverse Lines," Journal of the American Statistical Association, 9: 265-70, 1942.

Raisz, Erwin, General Cartography. New York: McGraw-Hill Book Co., Inc., 1938. 370 pp.

Sauer, Carl O., "The Survey Method in Geography and Its Objectives," Annals of the Association of American Geographers, 14: 17-23, 1924.

Spence, C.C., "The Development of Technique in Land Utilization Studies," Proceedings of the Canadian Agricultural Economics Society, 9th Annual Meeting, June, 1937. pp. 32-38.

Stamp, L. Dudley, "The Land Utilisation Survey of Britain: A Paper read at the Afternoon Meeting of the Society on 16th February 1931," The Geographical Journal, 78: 40-53, 1931.

________, editor, The Land of Britain. The Report of the Land Utilisation Survey of Great Britain. 9 volumes, London: Geographical Publications, Ltd., 1937 - 1944.

U.S. National Resources Planning Board, Land Classification in the United States. Washington: U.S. Government Printing Office, 1941. 151 pp.

Wrigley, P.I., "Land Use in Pennsylvania," Pennsylvania Agricultural Experiment Station, Bulletin No. 317, 1935. 39 pp.

II. THE HUNTINGDON - CHATEAUGUAY AREA.

Antevs, Ernst, Retreat of the Last Ice Sheet in Eastern Canada. Canada Geological Survey, Memoir No. 146, 1925. 142 pp.

Atwood, Wallace W., The Physiographic Provinces of North America. Boston: Ginn and Co., 1940. 536 pp.

Auclair, E.J., Histoire de Chateauguay, 1735-1935. Montréal: Librairie Beauchemin, Ltée., 1935. 239 pp.

Auer, V., Peat Bogs in Southeastern Canada. Canada Geological Survey, Memoir No. 162, 1930. 32 pp.

Baril, Roger, "Etudes Pedologiques des Sols du Quebec," Agriculture, 5: 3-35, 1948.

Canada Geological Survey, Excursions in the Neighborhood of Montreal and Ottawa. International Geological Congress Guide Book No. 3, 1913. 162 pp.

Census of Canada, 1941, Volume VIII, Agriculture. Dominion Bureau of Statistics, 1947. 1736 pp.

Dansereau, Pierre, L'Erablière Laurentienne. II: Les Successions et leurs Indicateurs. Contributions de l'Institut Botanique de l'Université de Montréal, No. 60, 1946. (Reprinted from Canadian Journal of Research, C, 24: 235-91, 1946.)

Dresser, J.A., and T.C.Denis, Geology of Quebec. Vol. II, Descriptive Geology. Province of Quebec, Department of Mines, Geological Report No. 20, 1944. 544 pp.

Fenneman, Nevin M., Physiography of Eastern United States. New York: McGraw-Hill Book Co., Inc., 1938. 691 pp.

Girard, H., Peat in Quebec. Its Origin, Distribution, and Utilization. Province of Quebec, Department of Mines, Geological Report No. 31, 1947. 48 pp.

Quebec Bureau of Mines, Annual Report of the Quebec Bureau of Mines for the Calendar Year 1930, Part D. 1931, 195 pp.

Sellar, Robert, The History of the County of Huntingdon, (Quebec) and of the Seignories of Chateauguay and Beauharnois from Their First Settlement to the Year 1838. Huntingdon, P.Q.: The Canadian Gleaner, 1888. 584 pp.

Wilson, Alice E., Geology of the Ottawa - St. Lawrence Lowland, Ontario and Quebec. Canada Geological Survey, Memoir No. 241, 1946. 65 pp.

III. MAPS.

Canada Department of National Defence, National Topographic Series, Canada, Sheet 31G, Ottawa (Ontario-Quebec). Compiled, drawn and printed by the Geographical Section, General Staff, Department of National Defence, 1937. Topography from maps of the National Topographic Series, and photographs by Royal Canadian Air Froce. Scale: 4 miles to 1 inch.

________, National Topographic Series, Canada, Sheet 31H, Montreal. Compiled, drawn and printed by the Geographical Section, General Staff, Department of National Defence, 1940. Topography from maps of the National Topographic Series. Scale 4 miles to 1 inch.

________, National Topographic Series, Canada, Sheet 31H/4, Chateauguay, Quebec. Original Survey 1907, Resurveyed 1931 with aerial photographs taken by R.C.A.F., printed 1935. Scale: 1 mile to 1 inch.

________, National Topographic Series, Canada, Sheet 31G/1, Huntingdon, Quebec. Published 1909, reprinted 1944 with revised road classification. Scale: 1 mile to 1 inch.

Lobeck, A.K., Physiographic Diagram of North America. New York: The Geographical Press, 1948. (2 maps). Scale: (approximately) 1:12,000,000.

Quebec Department of Agriculture, Preliminary Soils Maps of the Counties of Huntingdon and Chateauguay. (Blueprints secured from the Department of Agriculture, Ste.Anne de La Pocatiere, P.Q., 1948.) Scale: 2 inches to 1 mile.

Sanford-Evans Statistical Service, Quebec Population Maps. Map No. 4, Montreal-Quebec City. Winnipeg: Sanford-Evans Statistical Service, 1946. Scale: 7 miles to 1 inch.

APPENDIX A

A GLOSSARY OF TERMS USED FOR THE DESCRIPTION OF THE HEXAGONAL SAMPLING SYSTEM.

Sample. An area within which land use is studied and mapped in detail. Sometimes called Sample Block, or Block. In this investigation the samples were square-shaped.

Sample Size. The area of each sample, measured in square miles. All the samples used in any one survey are of equal size.

Sample Spacing. The distance between the geometrical center of one sample and the centers of the nearest adjacent samples. The sample spacing is constant for any one survey.

Total Sample. The size of each sample multiplied by the number of samples used in any one survey.

Hexagonal Pattern. The pattern formed by a number of samples when they are located at the centers of contiguous hexagons.

Hexagonal Grid. A network of contiguous hexagons so arranged as to cover completely the area to be surveyed. One sample should be located at the center of each hexagon.

Grid Dimensions. A collective term, referring to both the sample spacing and the sample size used for any one survey.

Sampled Area. The hexagon in which each sample is located. In theory, each sample is assumed to be representative of conditions in its sampled area.

Total Sampled Area. The area of the size and shape given by the hexagonal grid used in any one survey. The boundaries of the total sampled area may not coincide with those of the total area.

Total Area. The area to be surveyed, whether it be a statistical division, or watershed, or other area or region. Also called Entire Area, or Whole Area.

APPENDIX B

LIST OF IDENTIFIED TERRAIN TYPES

Well-drained Clay Plains

113311
113312
1133a12
113411
113511
113812
114211
114311
114411

123211
123311
123321
123322
123411
123412
124311

143312
143322
143412

173211

8132a12
8135a12

823412
824412 a

Ill-drained Clay Plains

115211
115311
115322a
115411
115811

Sand Plains

21311

222111
2231a13a

Bogs and Half-bogs

310311
314511
314611
314622
315-11
315111
315321
315611
315621

Rock Outcrop

712131a
712134a

Beach and Terrace

513522
515734a

523523
523723

5335a34a
533714a

5421a33
5421a34
5431a23
5434a12
543423
543522
543523
5435a23
543734a
544812

553522
553714a
553733

List of Identified Terrain Types (continued)

<u>Ridges</u>

615134a
615213a

623134a
623a22
623224
623a24a
623413
6234a23
6234a23a
6234a24a
6235a23
6235a24a
623723
623723a
623724a
6241a34a
624724
624724a
625323
625324

632724a
633134
6331a23
6331a24a
6333a24
6334a24a
6335a23
6335a24a

633724a

6431a22
6431a23a

653724A

823723
824723
824724a

<u>Other</u>

413422
414422
415111
415734a

424412

824523a
825412a

APPENDIX C

COMPARABILITY OF THE LAND USE CATEGORIES OF THE CENSUS WITH THOSE OF THE SURVEY.

The land use categories used in this thesis for comparative tests of sampling accuracy are not strictly those of either the census or the sampling survey. Instead, the categories are composite in nature, representing an attempt to find those categories in which discrepancies between the various sets of figures would not be due to any non-comparability of the categories.

Figure 37 shows diagramatically how the categories of the census and of the survey are combined to form the composite categories. Qualifying remarks for each composite category are given, and reference is made to census definitions appropriate in each case. The appendix is concluded with a section dealing with the conversion of the census figures (which are given in acres) to percentages of the total area.

IMPROVED LAND.

The category of improved land is exactly comparable as between the census and the sampling survey. The census definition of improved land is as follows:

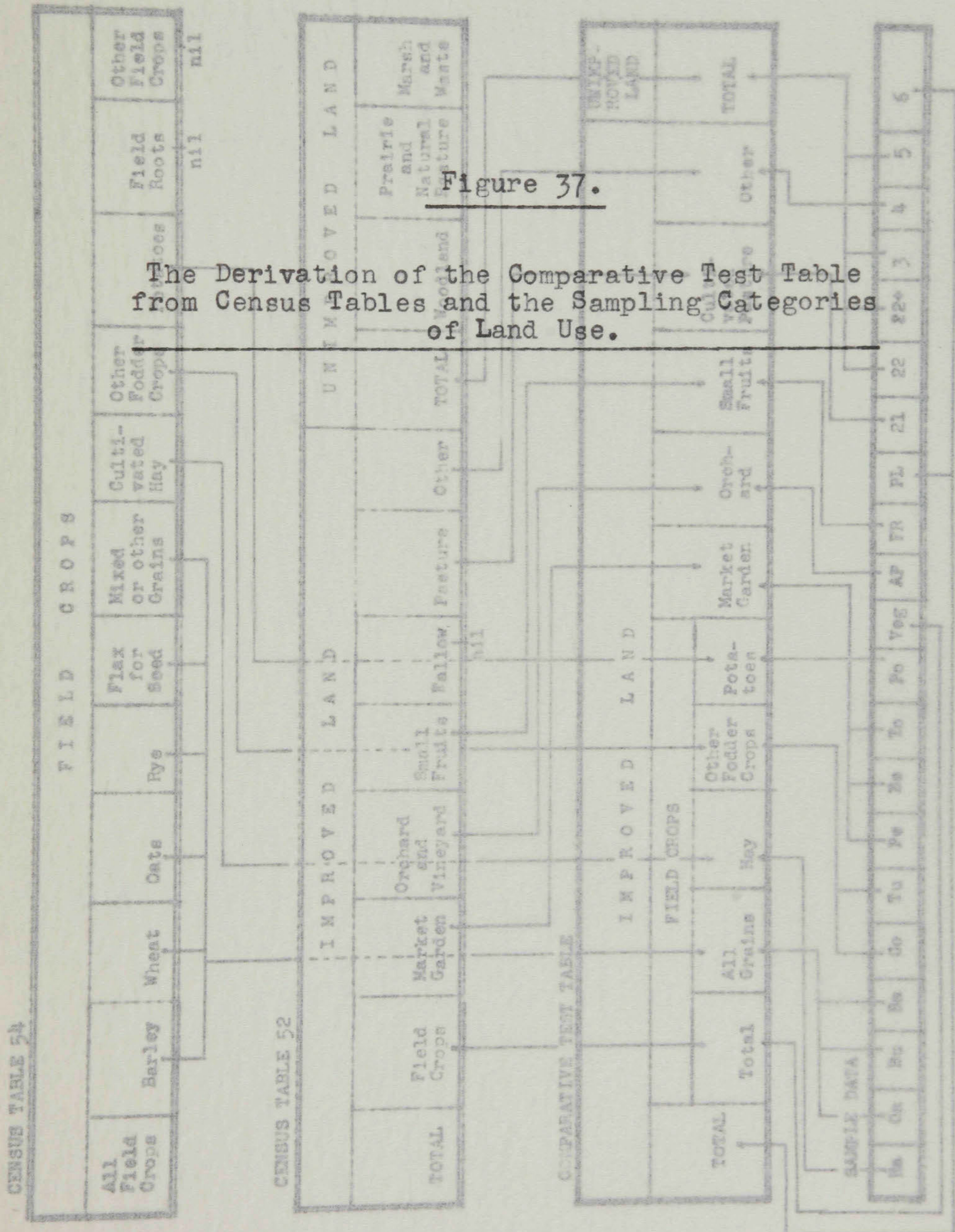
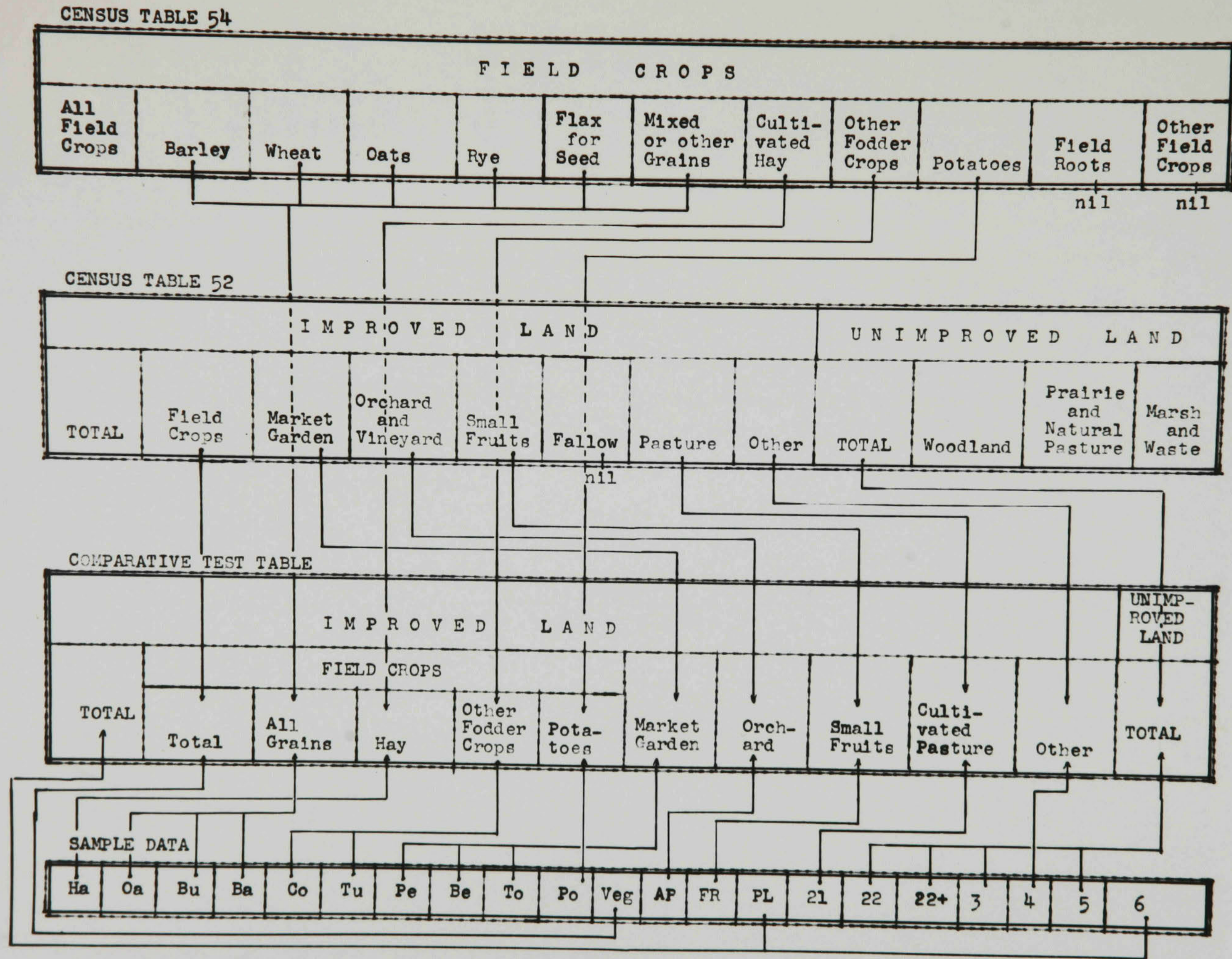


Figure 37.

The Derivation of the Comparative Test Table from Census Tables and the Sampling Categories of Land Use.


CENSUS TABLE 54
FIELD CROPS
All Field Crops
Barley
Wheat
Oats
Rye
Flax for Seed
Mixed or other Grains
Culti-vated Hay
Other Fodder Crops
Potatoes
Field Roots
Other Field Crops
nil
nil
CENSUS TABLE 52
IMPROVED LAND
UNIMPROVED LAND
TOTAL
Field Crops
Market Garden
Orchard and Vineyard
Small Fruits
Fallow
Pasture
Other
TOTAL
Woodland
Prairie and Natural Pasture
Marsh and Waste
nil
COMPARATIVE TEST TABLE
IMPROVED LAND
UNIMP-ROVED LAND
FIELD CROPS
TOTAL
Total
All Grains
Hay
Other Fodder Crops
Pota-toes
Market Garden
Orch-ard
Small Fruits
Culti-vated Pasture
Other
TOTAL
SAMPLE DATA
Ha
Oa
Bu
Ba
Co
Tu
Pe
Be
To
Po
Veg
AP
FR
PL
21
22
22+
3
4
5
6

62. Area of improved land ....acres
(Include all land that has been brought under cultivation and is now fit for the plow. The answer to this inquiry must equal the sum of inquiry No. 62 (a), (b), (c), and (d)).

(a) Area under all crops ....acres
(Include all field, garden, and orchard crop land.)

(b) Area of land summer fallowed ....acres

(c) Area of improved land in pasture ....acres
(Include all cultivated land seeded to pasture)

(d) Area of other improved land ....acres
(Include any idle improved land also area of buildings, barnyards, lanes, etc.) (1)

The comparable category for the sampling survey is the sum of all cropped land (including plowed land), built up land, rotation pasture, and idle land. Except for buildings, improved land is all land fit for plowing.

<u>All Field Crops</u>. The figures given in tables 52 and 54 of the census for the category all field crops do not agree. This is because some double cropping occurs, and hence some areas are reported twice. In table 54, the aggregate areas are reported, but in table 52, each area is reported only once. Since double-cropping could not be taken into account in the sampling study, the category "all field crops" is only comparable when the smaller

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(1) Census of Canada, <u>Vol. VIII</u>, <u>Agriculture</u>, Appendix A, General Farm Schedule. p. 1707.

figure, that from table 52, is taken.

In Huntingdon county, the amount of land double-cropped is 1.2 percent of the area of all field crops; in Chateauguay, it is 0.8 percent.

Before proceeding to a discussion of the separate field crops, the census categorization should be noted. The following list is taken from the General Farm Schedule:(2)

GRAINS

64. Wheat, fall
65. Durum wheat, spring sown
66. Other wheat, spring sown
67. Barley
68. Oats
69. Rye, fall sown
70. Rye, spring sown
71. Corn for husking (Do not include corn for canning)
72. Flaxseed
73. Buckwheat
74. Beans
75. Peas
76. Mixed or other grains

HAY AND FORAGE CROPS

77. Timothy
78. Timothy and clover
79. Alfalfa
80. Sweet clover
81. Brome grass
82. Other tame hay
83. Prairie hay or natural grass
84. Corn for ensilage or fodder
85. Grain hay (a) Oats
    (b) Oat mixtures
    (c) Other grains
86. Other fodder crops

POTATOES AND ROOTS

87. Potatoes
88. Turnips and Swedes
89. Mangolds and sugar beets for feed
90. Sugar beets for sugar
91. Other field roots

MISCELLANEOUS FIELD CROPS

92. Tobacco
    (a) for flue curing
    (b) other
93. Flax for fiber
94. Other field crops such as hemp, hops, rape, etc.

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(2) Ibid, Appx. A, p. 1707.

To obtain the total of all field crops from the sampling survey, it was first necessary to determine which crops would have been listed by the census under all field crops, and which would have been listed under orchard and market garden. The appropriate definition follows:

> Fruit Farms and Market Gardens (Fruit and Vegetable Farms). - - These terms, as used in the 1941 census, apply to (a) farms which produced for sale in 1940, either vegetables (other than potatoes and turnips), vegetable plants, vegetable seed, nursery products, greenhouse products, or small fruits to the value of $50 or more, and (b) farms where there were 50 fruit trees or more in 1941. Statistics of fruits and vegetables on these farms were enumerated on the special fruit and vegetable schedule, while the statistics of vegetables and fruits of farm gardens and orchards were recorded on the general farm schedule (Form 2). (3)

According to the census, peas and beans may be grown either as field crops (General Farm Schedule) or as Vegetables (Fruit and Vegetable Farm Schedule). Some areas of peas and beans appear in the sampling results, but it is impossible to tell whether these areas would have been counted as field crops or as part of market gardens. It seems likely, however, that because of the concentration of these crops in specialized region of the test area they would appear under table 54, Market Gardens. For comparative purposes, the areas of peas and beans, along with tomatoes, have been equated with market gardens, although some error is probably involved in so doing.

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(3) <u>Idem</u>, "Explanation of Terms," p. 151.

In sum, the category all field crops (using the figure given in Census Table 52) is equated with the total area of hay, all grains, other fodder crops (each of which appears as a separate category) and vegetables. This latter category of undifferentiated vegetables, noted in the sampling results, included mainly farm gardens, and hence would have been enumerated in the census with all field crops.(4)

<u>Hay</u>. Some error in the hay totals may have resulted from wrong identification during the sampling survey, especially during the latter part of the field work. At this time, all hay had been harvested, and often cattle were being put to graze on the stubble fields. Some of these fields may have been mistakenly identified as improved pasture.

On the other hand, the census does not make clear just what is included in the category Cultivated Hay of table 54. The problem is whether or not the "grain hays" of the General Farm Schedule (see above, p. 157) are listed in table 54 as hay, or as oats and other grains. It has been assumed that "grain hays" are listed with "grains" and not with "cultivated hay",

<u>All Grains</u>. It has been found impossible to differentiate between the various grains for comparative purposes. The category of oats, as used in the field study, actually includes

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(4) See above, p. 156, Item 62 (a), and citation, p.158.

many other grains. Mixed planting of oats, such as oats with timothy, clover, or buckwheat, were identified simply as oats. Probably many other small grains such as barley, rye, and wheat were also identified as oats, for it is only possible to tell these grains apart when they are fully ripe. This was only the case during a short period of the field work.

Buckwheat has a characteristic appearance at all stages of growth and leaves a distinctive stubble. Buckwheat was identified as such (except when it occurred in mixed plantings) but the census does not have a separate category for buckwheat with which comparisons might be made. Barley was only positively identified in two samples; undoubtedly other areas of this grain did occur but were noted as oats.

The category of all grains, used in the table of comparisons, includes oats, buckwheat, and barley from the samples; this is compared with the figures for wheat, barley, oats, rye, and mixed or other grains from the census table 54.

<u>Other Fodder Crops</u>. Most of the corn grown in the test area was meant for fodder and ensilage, although some was being grown for other purposes. This distinction, however, could not be made in the field, so that it was necessary to equate corn (along with turnips) to "other fodder crops" despite the possible error involved in so doing.

<u>Potatoes.</u> This is one of the few categories which is strictly comparable as between the census and the sampling survey.

It is, unfortunately, one of the minor land uses.

Market Gardens. This category has already been explained in connection with "all field crops". It includes the peas, beans and tomatoes of the sampling survey.

Orchard. Apple acreages may appear under either of two categories in table 52 of the census, depending on whether or not fifty or more trees were reported per farm. The apple acreages for those farms having less than fifty trees appear under "field crops", but for those having more than fifty, the acreages are listed under "orchards and vineyards".

Although this distinction could be approximated through a close study of individual samples, it was felt that such a procedure would only complicate matters; accordingly, apples were equated without distinction to orchards and vineyards. (There are no vineyards in the area.)

Small Fruits. Both categories of small fruits are quite comparable. This is another one of the minor uses, and in the test area consists almost entirely of raspberries.

Cultivated Pasture. Although both categories are comparable, some error may have resulted through mistaken identification as explained above under "hay".

Other Improved Land. The only unaccounted-for item of improved land in the sampling survey is built-up land. Here, the census includes farm roads and buildings, but does not include public roads and railways. The sampling survey includes the latter but disregards the farm roads.

UNIMPROVED LAND

Unimproved Land includes all land not ready or fit for cultivation. The census definition is as follows:

63. Area of unimproved land ....acres
(The answer to this inquiry must equal the sum of the answers to inquiry No. 63 (a), (b), and (c).)

(a) Area of woodland (1) Natural .....acres
(2) Planted .....acres
(Include as woodland all farm woodlots, maple bushes, land leased for firewood, and cut-over land with young growth which has or will have value as wood or timber.)

(b) Area of unbroken prairie, bush, stump or marsh, unimproved hay and pasture land .....acres
(Include all natural prairie, bush, or stump land, whether leased, rented, or owned, that has never been ploughed and is now used for hay or pasture.)

(c) Area of wet marsh, slough, rocky or waste land ....acres (5)

The sum of all types of rough pasture, natural vegetation, and waste land is comparable with the census category of "unimproved land". No sub-categories can be compared, as is evident when the above quotation is compared with the sub-categor-

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(5) Idem. p. 1707.

ies used in the survey.[6] It should be noted here that although the category unimproved land is itself comparable, the figures are not comparable until a correction has been made in the census figures to account for unimproved land not in farms. This correction is explained in the following section.

CONVERSION OF CENSUS DATA TO PERCENTAGES.

Since the land use data from the sampling survey are expressed in percentages of the total area, it was necessary to convert the acreage figures of the census to the same terms. This was not as simple as it may appear, for the total land area is a necessary factor in the calculation, and a figure for this cannot be obtained from the census data directly.

Figures for total land areas are given for counties, but not for townships. The only inclusive figure that can be obtained for townships is the amount of land in farms. The test area, however, is made up of a group of townships which do not constitute two entire counties, but the major portion of two counties. The available data are given below:

	Chateauguay		Huntingdon	
Total land area entire county	169,600	acres	231,040	acres
Area in farms, entire county	147,059	"	216,372	"
Area in farms, test area portion of county	126,527	"	213,234	"

(6) cf. Table I.

In order to obtain a figure for the total land area of the study portion, it was assumed that the ratio of total land to land in farms was equal for every part of each county. By simple cross-multiplication, a figure for the total land area of the study portion of each county was then obtained. The result for Chateauguay was 145,800 acres, and for Huntingdon 224,100 acres, giving for the entire test area 369,900 acres.(7)

Calculation of Improved and Unimproved Land Percentages. For each use which falls into the general category of improved land, the percentage which this use is of the total area was calculated in the ordinary way. For the unimproved category, however, a correction was considered necessary.

The discrepancy between the area of land in farms and the total land area must necessarily be the area of land not in farms. As such, it cannot be cropped land, but must represent either built-up areas or unimproved land, waste or idle land of some kind. It was assumed that the land not in farms was almost exclusively unimproved. Hence, to the amount of unimproved land reported on farms, must be added the unimproved land not on farms, and this total used to calculate the percentage of unimproved land. To the 136,978 acres of unimproved land on farms, the 30,139 acres of unimproved land not on farms was added,

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(7) This figure equals 578 square miles, and compares very favourably with the figure of 580 square miles which was obtained by measuring the map area with a planimenter.

giving a total of 167,117 acres or 45.2 percent of the test area. This correction was applied to the test area, but not to the Hemmingford homogeneous area, since field studies did not reveal any extensive amounts of land not in farm within that region.