An Experimental Sample
Land Utilization Survey

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CONTENTS

I. INTRODUCTION.
   The Need for Land Use Surveys. 1
   Sample Surveys.
   Scope and Objects of the Survey. 4

II. THE AREA OF THE SURVEY.

III. THE SURVEY FRAME.

IV. SAMPLING.
   Choice of Sample Unit. 13
   Division of Frame Area into Sampling Units. 15
   Sampling Method.
   Division of First-Stage Units into Sub-Units. 24

V. CLASSIFICATION OF LAND USE.
   Cultivated Land. 27
   Uncultivated Land. 28

VI. MAPPING OF SAMPLING UNITS.
   Preparation of Large Scale Unit Maps. 30
   Field Mapping.
   Survey of Arable Stratum Unit 13. 32
   Survey of Bush Stratum Unit 39.
   Abstraction of Data from the Unit Map. 39

VII. ANALYSIS OF RESULTS.

VIII. CONCLUSIONS.

IX. RECOMMENDATIONS.

X. SUMMARY.

XI. REFERENCES.

APPENDICES.
   A. Tables.
   B. Maps.
This dissertation is one of five reports on a sample land utilisation survey. Such a survey is considered an important exercise for Postgraduates but is not in all respects ideal project material. In the first place it is necessary to have a team (of five people this year) to undertake the field work, and second it is necessary to restrict the scope of the survey rather artificially so that it can be completed in the time available.

In order to minimise the first difficulty certain aspects of the whole survey were made the responsibility of an individual student. Each was required in turn to behave as though he was the senior officer responsible for the whole work. This student's particular responsibilities were divisions of frame into first stage sampling units, division of first stage units into second stage sampling units, and sampling in general, and he was required to report on these more fully than on others. The emphasis given to various aspects of the whole project is therefore intentionally uneven.

The supervisor imposed artificial restrictions on the survey in order to keep it within manageable bounds. The total area was restricted by him to the part of the Colony that was most easily accessible to the student; he decided that no Northern range land and none of the populous urban area along the Eastern main road should be included.

The five students participating in this project have been restricted to the simplest equipment and the standard maps; they have not been allowed any outside labour to help them in the field or clerical assistants to help with mapping and area measurements.
I. INTRODUCTION

THE NEED FOR AGRICULTURAL SURVEYS.

In common with the rest of the world the Colonial Territories are faced with the problem of supporting an increasing population on limited areas of land. The required increases in agricultural production can only be obtained by making better use of land already occupied and by opening up undeveloped land. Before any development plans can be made it is essential for the Government of a country to have basic information on all aspects of land use, but in most countries very little reliable information of this nature exists. To obtain this vital information agricultural censuses and surveys are essential and their need was recognised by the United Nations Organisation who drew up plans for a 1950 World Census of Agriculture (F.A.O. of U.N.O. 1948). In underdeveloped countries the purpose of the census was to obtain information on the following points:-

(a) The number of agricultural holdings and their practical characteristics.
(b) The number and characteristics of the people who secure their livelihood from agriculture.
(c) Areas under crops and livestock.
(d) The volume of production of all agricultural products.

From a survey of this nature reliable estimates can be made for the following points:- the amount of land required to support a family; the amount of land already cultivated and the amount of additional land available; the number of livestock and the optimum stocking rate; the degree of soil erosion; the relative profitability and productivity of different crops, different systems of farming and of farms in different regions. This and other information is invaluable in planning research programmes, extension work,
settlement schemes, marketing schemes, etc. This information is also useful in planning Government agricultural and economic policy as it indicates whether or not an export crop economy is more desirable than self sufficiency in food production.

SAMPLE SURVEYS.

Sampling is the selection of a part of an aggregate of material to represent the whole aggregate. To avoid bias in a sample it is essential that the sample should be selected at random.

A sample survey is a survey carried out on a properly selected sample to give an estimate for the whole population. In survey work the whole population consists of a large number of separate units which are often dissimilar in various respects and so a sample cannot be exactly representative of the whole population. However by using modern scientific sampling techniques the random sampling errors can be made sufficiently small not to invalidate the results for the purpose for which they are required and the magnitude of these errors can be calculated by statistical methods. (Yates, 1953.)

In cases where information on all the individual units of a population is required a complete survey must be made. Sample surveys may be used in cases where results are required for the population as a whole but not for the individual units. They may also be used in cases where information is required for different parts of the population, such as towns and districts, provided that these parts contain a sufficient number of units. However in this latter case a larger sample must be taken than in the former case to obtain results of the same degree of accuracy. In certain cases the sample may have to be so large that there is little point in using a sample survey instead of a complete survey.
In cases where their use is permissible sample surveys have several advantages over complete surveys.

(a) The amount of effort and expense required to collect the information in a sample survey is very much less than that required for a complete survey. In fact the effort and expense required often make country wide complete surveys impractical.

(b) Fewer staff will be required to collect data in a sample survey and therefore it is possible to employ staff of a high grade. This results in more accurate recording of data. As the information is collected from only a small proportion of the population the completeness and accuracy of the data is more easily ensured.

(c) More detailed information can be obtained in a sample survey. Owing to the reduced volume of material to be handled the quality of abstraction can be improved and more detailed analyses made.

(d) Sampling may increase the speed of a census both in the execution of field work and in the analysis of results. This is useful in surveys such as those made to estimate crop yields or fertiliser requirements where the results are required quickly.

These advantages may enable a sample survey to be more accurate than a complete survey in spite of sampling errors. The random sampling errors are always assessable.

Though the mathematical principles of sample surveys are well established, little research has been done on their practical application in undeveloped countries. The United Nations Sub-Commission on Statistical Sampling were particularly impressed with the need for a wider use of sampling in the less developed areas and, at their suggestion, a manual on sampling was prepared by Dr. Yates to assist in the execution of the 1950 World Census. (Yates. 1953). In the less
developed countries there are numerous problems which are not found in more highly developed countries and these problems vary widely with local conditions. It was felt that an experimental sample land utilisation survey would yield valuable information on survey problems under Trinidad conditions.

**SCOPE AND OBJECTS OF THE SURVEY.**

The scope of the survey was limited by many peculiar features which were due to the survey being run as a student project and not as a normal Government survey. The time available for field work was limited to the three weeks of the Christmas vacation and the time available for the whole project was eight months. Only very limited funds were available whilst the number of survey enumerators was restricted to the five students doing the project. The use of car transport also had to be kept to a minimum.

These limitations influenced the selection of the area to be surveyed. This was confined to an area of 176 square miles of the Northern Plain of Trinidad. The reasons for this choice will be considered later in the section dealing with the Area of the Survey.

The nature of the survey was also influenced by the limited time and facilities available.

Crop yield estimates and studies of cultivation techniques were impossible because a full year's recording was required.

It was decided that no form of data would be collected which involved interviewing farmers as the past experience of students and of the Economics Department of the I.C.T.A. had shown that this was an extremely laborious method of collecting data as farmers were hard to contact and often hard to understand. This precluded investigations into size of holding; farm income; housing conditions; marketing, etc.
Livestock counts were also excluded from the survey although they would have given valuable information on the utilisation of the land. Animals are difficult to count because of their mobility and it was felt that the task would be too great for so few enumerators.

Investigations into the degree of erosion of the land were also considered, but rejected because of the amount of work entailed.

It was finally decided that the scope of the survey should be confined to estimating the area of land occupied by each class of land usage.

The main object of the project was to evolve a method of survey suitable for the conditions and to carry out the survey in order to test the method. The survey was therefore regarded as an experiment and it was not primarily intended to provide results of practical value to Trinidad agriculture. As this was the first survey of its kind attempted in Trinidad it was felt that this survey should be in the nature of a preliminary investigation. It could then be followed by a larger or more detailed survey based on experience gained in the preliminary survey.

The other main purpose of the project was to provide the five members of the team with knowledge and experience of survey work that would be useful to them as Agricultural Officers in the Colonial Empire. The survey was designed as far as possible so that the methods could be used under conditions likely to be found in other parts of the Colonial Empire.

The survey was run as a team effort but to provide practice in handling field survey staff the work was divided up and each member of the team supervised certain parts of the survey. The writer supervised the task of dividing the frame area into sampling units and also the field survey work of two
units. The duty of the supervisor was to do the preliminary planning and to guide the work of the team. For the purposes of the survey the supervisor regarded the other members of the team as being untrained African assistants and so the work was more thoroughly planned than was actually necessary, foolproof instructions being issued to the team.

During the Christmas term the team met frequently under the chairmanship of Dr. A.L. Jolly to plan the survey. At these meetings the problems of sampling, land use classification and field survey methods were discussed. All the preparations for the survey were made during the Christmas term, 1954, and the field survey work was carried out during the Christmas vacation. The abstraction and analysis of the data was carried out from January to May of 1955.

Little information of agricultural interest would have been obtained.

(b) The Caroni Swamp on the west of the region was excluded for the same reason.

(c) The forest reserve areas in the east of the region were also excluded for the same reason.

(d) All land to the south of the region was excluded in order to save travelling long distances to collect information.

(e) The urban area along the Eastern Main Road was excluded because the land was being used primarily for non-agricultural purposes and because the complexity of the area would have made it very laborious to survey.

The climate of the area is not subtropical. On the west coast the rainfall is approximately 50 inches per annum with 4 or 5 dry months. The rainfall increases westward to over 60 inches per annum with only 1 or 2 dry months.

The area is divided into the topographical

II. THE AREA OF THE SURVEY

The area of the land covered by the survey was part of the Northern Plain of Trinidad. This region of 176 square miles stretches from the Churchill Roosevelt Highway in the north to Couva in the south, and from the coast in the west to Talparo and San Raphael in the east, as shown on the map (Appendix B.1.).

The survey was restricted to this region because it was the most convenient and the most suitable area of land. All the adjoining regions were excluded from the survey for the reasons given below.

(a) The Northern Range of Trinidad was excluded from the survey because the impassable nature of the terrain would have made it difficult to survey whilst little information of agricultural interest would have been obtained.

(b) The Caroni Swamp on the west of the region was excluded for the same reason.

(c) The forest reserve areas to the east of the region were also excluded for the same reason.

(d) All land to the south of the region was excluded in order to save travelling long distances to collect information.

(e) The urban area along the Eastern Main Road was excluded because the land was being used primarily for non-agricultural purposes and because the complexity of the area would have made it very laborious to survey.

The climate of the area is wet subtropical. On the west coast the rainfall is approximately 50 inches per annum with 4 or 5 dry months. The rainfall increases westwards to over 80 inches per annum with only 1 or 2 dry months.

The area is divided into two topographical
regions. The greater part of the area is flat, low-lying land but to the south and east is undulating country from 100 to 300 feet above sea level with one hill rising to 582 feet.

The flat area is mostly composed of alluvial flats and the soils formed are hydromorphic due to poor drainage conditions. They vary from bog soils of the Caroni Swamp to poorly drained clay soils which cover most of the area. To the north east of this flat area are found sandy soils which form savanna land.

In the area of undulating land the soils are mostly clays but in the east central region sands occur on the hill tops.

Sugar cane is grown on the flat area by both estates and peasant farmers. Chenery classifies this sugar cane land as being of medium to low productivity. (E.M. Chenery. 1939).

The savanna land, which is of low fertility, is sparsely cultivated and mostly remains under its natural vegetation of Savanna Grassland and Palm Marsh Forest.

The undulating country is mostly covered by its natural vegetation of Evergreen Seasonal Forest, though a small proportion of this has been cleared mainly for the cultivation of cocoa.

The area is supplied with a network of tarred and metalled roads, though these are less numerous in the south east. The unmetalled roads and traces are passable to cars only in the dry season.

Where there are no roads or traces access to the land is almost impossible owing to the impenetrable nature of the forest, the swamps and the mature sugar cane. This problem, which is peculiar to the wet but not to the dry tropics, severely restricted the choice of survey methods.
III. THE SURVEY FRAME

The frame defines the geographical scope of the survey and the categories of material covered. The problem of finding a suitable frame was discussed during the Christmas term and the following possible frames were considered:

(a) The Population Census of 1946.
(b) A list of farmers.
(c) A list of villages.
(d) A map of the area.

The Population Census was considered unsuitable because it would have involved contacting individuals and interviewing them. Interviews were ruled out for reasons mentioned in the Introduction.

No suitable list of farmers existed and even if one had been available it would not have been used because of the interviews involved. In the 1949-50 Agricultural Survey of Basutoland a list of groups of householders was obtained from the 1946 Population Census and used as a frame. (Douglas and Tennant, 1952.) A frame of this nature was impractical in this case where only a few enumerators were available who were not local residents.

A list of villages was not considered a suitable frame because in Trinidad there is no form of tribal or village organisation and many farmers live on their land away from the villages.

A map was considered the most suitable frame as its use had none of the disadvantages mentioned. A map of the area formed a complete frame and was one which would not become out of date. The same frame could therefore be used for later surveys and for surveys of a different nature if required.

A map of scale 1:50,000 or 1.267 inches to the mile was chosen as the frame. Large scale Ward maps were
available but it was ruled that these should not be used because such maps were not likely to be available for less developed areas in the Colonial Empire.

Having chosen the type of frame it was then necessary to select the boundaries for the frame map. It was essential that the boundaries should be features on the map easily recognisable in the field. Roads were used as far as possible as they were the most accessible form of boundary.

For the northern boundary the Churchill-Roosevelt Highway was selected because it approximately divided the agricultural region of the Northern Plain from the urban areas of the Eastern Main Road (Appendix B. 1.).

For the eastern boundary the road running southwards from the Churchill-Roosevelt Highway through Talparo to Flanagin Town was selected. It conveniently separated the agricultural region from the Forest Reserve areas to the east.

A convenient southern boundary was formed by the road running westwards from Flanagin Town through Gran Couva and Couva to the coast.

A convenient north-west boundary was the Madame Espagnole river and part of the Southern Trunk Road. This boundary divided the agricultural region from the Caroni Swamp.

The south-west boundary of the frame was the coastline.

The map used for the frame was the Ordinance Survey map of 1926. This did not show the Churchill-Roosevelt Highway or the Southern Trunk Road and it was therefore necessary to map these two roads.
IV. SAMPLING.

The writer was given the task of supervising the division of the frame into sampling units and of discussing sampling fully in his dissertation.

The advantages of sampling in surveys and the importance of using a suitable statistical method of selecting the sample have already been stressed in the Introduction.

The principal object of any sampling procedure is to secure a sample which, subject to limitations of size, will reproduce the characteristics of the population as closely as possible. The sample can never be absolutely representative of the population and error is inevitable. The error may be due to the influence of human judgement in choosing the sample, which is known as bias. Error is also caused by chance variation between the units in the sample and the units of the population not included in the sample, and this is known as random sampling error.

Bias can be avoided by selecting the sample entirely at random by drawing lots or using a table of random numbers. Certain restrictions may be placed on the random selection process which reduce the sampling error without introducing bias. Such restrictions include multi-stage sampling, stratification and the use of a variable sampling fraction and these processes will be considered later.

Having avoided bias by random selection the next step is to reduce the random sampling error. This error must be reduced to such a small degree that the estimate of the population value will be sufficiently accurate for the purpose for which it is required. Other things being equal the random sampling error is approximately equal to the square root of the number of units included in the sample (Yates. 1953). One method of reducing the
sampling error therefore is to have a large number of units in the sample. However in a large scale survey of this nature the field work is made expensive and laborious, if the sample consists of a large number of small units widely scattered over a large area.

In order to obtain a large number of units without having them widely scattered it was decided that multi-stage sampling should be employed. In multi-stage sampling the population is divided into a number of first-stage sampling units, which are sampled in the ordinary manner, the selected first-stage units being subdivided into smaller second-stage units which are also sampled. By using this process the ultimate units selected are in groups, which simplifies the field enumeration. A further advantage is that in making the frame only the first-stage units need be defined initially and later only the selected sample of first-stage units need be subdivided into second-stage units. In this survey the second point was extremely important as only a limited number of units could be defined on the map.

The final decision was to use two-stage sampling, taking a 100% second-stage sample. The plan was to define the first-stage units on the frame map. A sample would be selected and the selected first-stage units would be mapped and divided into second-stage units in the field. The field mapping of first-stage units was considered necessary because the small scale Ordinance Survey map did not contain enough detail to demarcate the small second-stage units. It was apparent that a great deal of field work would be entailed in mapping the first-stage units but once the maps were made the enumeration of land use data would be simplified. To get the maximum benefit from the work spent in mapping the first-stage units, it was decided that a 100% second-stage sample should be taken. This
method would give the maximum of data and, by giving the largest possible number of second-stage units in the sample, would reduce the sampling error. The actual number of second-stage units in each first-stage sampling unit was not specified at this stage. The proposed mapping technique would allow the first-stage units to be divided into as many sub-units as was considered desirable.

However the sampling error depends not only on the number of units in the sample but also on the variability of the units. From this it is apparent that the more variable the land use between units the larger will be the sample required to obtain a given degree of accuracy. Similarly, the more variable the size of the first-stage units, the larger will be the size of sample required. By using certain methods of selection the sampling error caused by this variability can be reduced. Of these methods stratification and the use of a variable sampling fraction will be considered in the section dealing with the Method of Sampling.

Having considered the general method of sampling to be employed it was then necessary to find a type of sampling unit suitable for the requirements.

**CHOICE OF SAMPLING UNIT**

The following types of sampling unit were considered:

(a) Units consisting of straight lines at even spacing across the map. This type of unit differs from the other types of unit as it is not an area unit.

(b) Area units consisting of political divisions on the map, i.e. Counties or Wards.

(c) Area units consisting of village districts.

(d) Area units composed of squares marked out as a grid on the map.

(e) Area units of a given acreage around defined points on the map.
(f) Units consisting of areas on the Ordinance Survey map bounded by physical features such as roads and railways.

(a) The first problem was to decide whether a line method of survey or an area method was the most suitable. A line survey has the advantage that accurate maps are not required and therefore this method is often used in underdeveloped regions and in forests. The usual method of enumerating data in a line survey is for an enumerator to follow a line across the country on a given compass bearing and record the length of each class of land he passes through. In Trinidad this method would be difficult because of the nature of the vegetation. Gangs of labour would be needed to cut a line through the forest, whilst lines could only be followed across sugar cane land after the cane harvest. This method was rejected because the field work had to be done before the cane harvest and because the expense of hiring labour to cut lines through forest land would have been too great.

Having decided to use area units it was then necessary to consider which of the five types listed was the most suitable.

(b) Counties and wards were both found to be unsuitable for use as sampling units because they did not divide the area into enough first-stage units. There were only two Counties and five Wards in the survey area.

(c) There were approximately forty named villages on the map of the area and it was considered that forty first-stage sampling units were too few. However, the main disadvantage was that there was no form of village organisation and many farmers lived far away from the villages. No village boundaries were marked on the map and so it would have been extremely difficult to define the units.

(d) and (e) The advantage of using area units
composed of either squares marked on the map or areas around selected points is twofold. In the first place the area can be divided into as many units as desired and so the optimum number of both first and second-stage units can be obtained. Secondly, the units formed are of equal size and this simplifies the procedure for selecting the sample and for estimating the population values and the errors. The disadvantage of this type of sampling unit is that units marked on the map are very difficult to locate and demarcate in the field. This point is especially applicable to Trinidad owing to the impenetrable nature of the vegetation and to the fact that in forest or mature sugar cane the low visibility makes it impossible to take compass bearings on distant landmarks.

(f) It was decided to use as units areas on the map bounded by physical features. The use of this type of unit avoided the serious disadvantages of the other types of unit. The use of roads and railways as boundaries clearly defined the unit in the field and also allowed easy access to the unit from all sides. A further advantage was that railways and first class roads were marked with quarter-mile stones which formed convenient landmarks for field mapping. Rivers formed less convenient boundaries as they were hard to follow. A drawback of this type of unit was that in less developed areas there were few suitable unit boundaries. A further disadvantage was that the units would be variable in size. These two problems will be considered later.

DIVISION OF FRAME AREA INTO SAMPLING UNITS

The writer was appointed to supervise the division of the frame area into sampling units. A tracing of the frame outline was made from the Ordnance Survey map of scale 1:50,000. The object of
marking the unit boundaries on tracing paper was to save defacing the maps. The frame area was divided into five approximately equal regions by tracing two railways and a road. These divisions are shown on the frame map (Appendix B.1).

The members of the survey team acted as assistants and each was allotted one region to divide into sampling units, the regions being allotted by drawing lots. Each assistant was given a tracing of his region. The direction of the North was marked and the boundary features were labelled so that he could find the region on the map and orientate his tracing correctly. The assistants were told first to look at their tracing and see if they could read the writing on it. If the writing was illegible, the letters being in the form of mirror images, this meant that they had got their tracing upside down and should therefore reverse it.

The supervisor gave the assistants instructions on the method to be used and demonstrated this method by dividing one of the regions into units. In his instructions the supervisor stressed the following points:

(1) The region should be divided up into as many units as possible provided the units formed were not smaller than 1/2 square mile. The reasons for having a large number of units have been considered. A minimum size of unit was essential because the first-stage units had to be large enough to be divisible into second-stage units.

(2) In order to determine whether or not an area was over 1/2 square mile, measuring grids drawn on tracing paper were provided. The squares on the grid were 1/3 inch x 1/3 inch, giving then an area of 1/9 square inch. Seven of these squares on the map corresponded to approximately 1/2 square mile or 320 acres in the field. The transparent grid was placed over the area to be measured
and the number of squares counted.

(3) Features on the map used as unit boundaries should be those that could be found easily in the field. Railways and first class roads were suitable. Third class roads were less reliable features, but could be used if the map showed that they were likely to be permanent. Permanence was indicated on the map by the presence of houses along the road or if the road ran between two villages. Sugar cane traces should not be used as they were liable to have changed since 1926 when the map was made. Sugar cane railways should only be used near factories, where the lines can be assumed to be permanent. The Caroni river should always be used as a boundary because if it crossed the middle of a unit it would hinder travel within that unit. Other rivers should not be used as boundaries because they were irregular and often changed course, thus differing from the course shown on the map. An additional disadvantage was that rivers often had overgrown banks which would make them difficult to follow.

When the assistants had inspected their work the unit boundaries of the five regions were traced onto the original frame tracing to give a complete unit map of the area.

There were 75 units and these ranged in size from \( \frac{1}{4} \) square mile to a vast unit of 30 square miles west of Talparo. It was considered that there were not enough units and that the variation in size was too great. Many units were so large that the work of field mapping them if they were selected would have been beyond the resources of the team.

In order to obtain more units of a smaller size the assistants were instructed to split up units of over 2 square miles by tracing in sugar cane traces, bridle paths and rivers. These boundaries were traced as dotted lines
so that they could be recognised on the tracing as doubtful boundaries and could be checked in the fields. When this had been done many large units still remained, especially in the south-west. It was therefore decided that field reconnaissances should be carried out to check all doubtful boundaries and to find traces not marked on the map which could be used for additional boundaries. Humphrys was appointed to organise these reconnaissances.

Members of the team visited regions around what have since become units 39, 42, 52, 60, 78, 81 and 109 and checked the doubtful boundaries (Appendix B. 1). Many new boundaries were found which were also marked on the unit tracing as dotted lines. The writer was sent out to find new boundaries to divide up a large region west of Talpare. A trace and a footpath were found which split this region into 3 smaller areas which now form units 53, 64 and 39. The writer also visited another large region in the south-east corner. One path was found which split this region into 2 smaller areas which now form units 77 and 78. It was found impossible to subdivide unit 78 as in its centre was an uninhabited area of forest not traversed by any paths.

When the division of the frame area was eventually completed there were 110 first-stage sampling units. As the total area was 176 square miles this meant that the average size of unit was 1.6 square miles or approximately 1,023 acres. There was one large unit, unit 78, which was approximately 10 square miles and the other units ranged in size from 6.2 square miles down to \( \frac{1}{2} \) square mile. The variation in size of unit is shown in the Table below.
Area of unit in square miles | Number of units
---|---
$\frac{1}{2}$ - 1 | 39
1 - $1\frac{1}{2}$ | 28
$1\frac{1}{2}$ - 2 | 20
2 - $2\frac{1}{2}$ | 10
$2\frac{1}{2}$ - 3 | 4
3 - 4 | 3
4 - 5 | 3
over 5 | 3

Total Area = 176  
Total units 110  
Average size of unit = 1.6 square miles.

**SAMPLING METHOD**

The general principles of the method of sampling used have already been discussed. In this section the application of these principles to the above frame of 110 first-stage sampling units will be considered.

The weakness of the frame was that there was only a relatively small number of first-stage units and the variability of these units was high. The variation in size of unit was shown in the Table. The units also vary widely in their land use. Observation had shown that the area was divided into two land use regions. Sugar cane and arable crops were found over the greater part of the area, but to the south and east was a region of forest and cocoa.

It was hoped that use of two-stage sampling would reduce the random sampling error by increasing the number of units in the sample. It was also necessary to use a method of selection that would reduce the error caused by this variability of the units. To achieve this object it was decided that the population of first-stage sampling units should be stratified. Stratification means the division of population into blocks of units in such a
manner that the units in each stratum or block are as similar as possible. Samples are taken from each stratum and estimates for the population of each stratum are made. In this way differences between the strata are estimated from the sampling error. Stratification also has the advantage that it gives information about the strata as well as the population as a whole.

The frame was divided into two strata, the Arable Stratum and the Bush Stratum. Field reconnaissances were made to find a suitable dividing line between these two strata. This division was found to correspond to the division between the elevated, undulating land of the south-west and the flat land over the west of the area. The division was drawn on the map by following unit boundaries that corresponded to the topographical division. Although they were on the flat land, units 23 and 11 were included in the Bush Stratum as they were largely forest. The strata are shown on the frame map (Appendix B. 1).

The Arable Stratum contained 127 square miles of land which was approximately 72 per cent. of the total area. It was divided into 92 units with an average size of approximately 1.38 square miles or 880 acres.

The Bush Stratum contained 49 square miles of land which was 28 per cent. of the total area. It was divided into 18 units with an average size of approximately 2.72 square miles or 1,750 acres.

It will be seen that by stratifying by land use a certain degree of stratification of units by size was also achieved. This was in fact one of the purposes of this stratification scheme. Most of the large units were found in the less developed areas in the south-west whilst the smallest units were found in the more highly developed land in the Arable Stratum. Though the variation in size of
unit within the strata was less than it was in the whole population, it was still considerable as is shown in the following Table.

<table>
<thead>
<tr>
<th>Size of Unit in Square Miles</th>
<th>Number of Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable Stratum</td>
<td>Bush Stratum</td>
</tr>
<tr>
<td>$\frac{1}{2}$ - 1</td>
<td>38</td>
</tr>
<tr>
<td>1 - $1\frac{1}{2}$</td>
<td>23</td>
</tr>
<tr>
<td>$1\frac{1}{2}$ - 2</td>
<td>19</td>
</tr>
<tr>
<td>2 - $2\frac{1}{2}$</td>
<td>6</td>
</tr>
<tr>
<td>$2\frac{1}{2}$ - 3</td>
<td>1</td>
</tr>
<tr>
<td>3 - 4</td>
<td>3</td>
</tr>
<tr>
<td>4 - 5</td>
<td>1</td>
</tr>
<tr>
<td>over 5</td>
<td>1</td>
</tr>
<tr>
<td>Total number of units</td>
<td>92</td>
</tr>
</tbody>
</table>

The use of multiple stratification was considered. This means stratification for two or more different characteristics. In this survey the units in each stratum could be stratified by size to form sub-strata.

The following multiple stratification scheme was considered. Arable Stratum divided into 3 sub-strata by size:

Sub-stratum A. 38 units of area $\frac{1}{2}$ - $1\frac{1}{2}$ square miles.  
B. 23 " " $1\frac{1}{2}$ - 3 " "  
C. 31 " " over 3 " "

Bush Stratum divided into 3 sub-strata by size:

Sub-stratum A. 7 units of area $\frac{1}{2}$ - 3 square miles.  
B. 7 " " $2$ - 4 " "  
C. 4 " " over 4 " "

For reasons given later the sample size was limited to 10 first-stage sampling units, 6 in the Arable Stratum and 4 in the Bush Stratum. From this it followed that if multiple stratification was used the Bush Stratum would have to be divided into two sub-strata and not three, so that two units could be selected from each sub-stratum. With 10 units to be
selected the sample would consist of two units from each stratum. It was considered that any benefit obtained by multiple stratification would be more than offset by the increase in sampling error caused by taking a sample of as few as two units. It was therefore decided that though sub-stratification for size was desirable it was impractical because with so few units a very high sampling fraction would be required.

Owing to the relatively small number of first-stage sampling units in the frame and the variability of the units in size within the strata, it was considered desirable to have a high sampling fraction in order to reduce the random sampling error. However the number of units which could be mapped was limited by the time available for the field work. It was considered that 10 first-stage sampling units could be mapped during the Christmas vacation and this represented a sampling fraction of 1 in 11. This was regarded as a minimum sample and plans were made to take an additional sample of five more units if time permitted, thus raising the sampling fraction to 1 in 7.3.

It was decided that a higher sampling fraction should be taken in the Bush Stratum than in the Arable Stratum because the units in the Bush Stratum were thought to be more variable in both size and land use. A sample of 4 units was taken out of 18 units in the Bush Stratum, giving a sampling fraction of 1 in 4.5. A sample of 6 units was taken out of 92 units in the Arable Stratum, giving a sampling fraction of 1 in 15.3.

The sample of 10 first-stage units was selected at random by means of Fisher's Table of Random Numbers. The units were numbered from 1 to 110 and random numbers between 1 and 999 were taken until 6 units from the Arable Stratum and 4 units from the Bush Stratum had been selected.
An additional sample of 3 units from the Arable Stratum and 2 units from the Bush Stratum was selected. This additional sample was to be enumerated if time was available.

Each member of the survey team was allotted two units at random and he was responsible for supervising the mapping of these units.

The units selected for the sample are listed below, together with their acreages and the name of the unit supervisor.

**Arable Stratum:**

<table>
<thead>
<tr>
<th>Supervisor</th>
<th>Unit</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castle</td>
<td>4</td>
<td>1035.0</td>
</tr>
<tr>
<td>Mitchell</td>
<td>13</td>
<td>745.3</td>
</tr>
<tr>
<td>Hannagan</td>
<td>49</td>
<td>536.0</td>
</tr>
<tr>
<td>Hannagan</td>
<td>52</td>
<td>1320.2</td>
</tr>
<tr>
<td>Devonald</td>
<td>56</td>
<td>1147.0</td>
</tr>
<tr>
<td>Humphrys</td>
<td>71</td>
<td>718.9</td>
</tr>
</tbody>
</table>

**Total** 5502.4 acres

**Bush Stratum:**

<table>
<thead>
<tr>
<th>Supervisor</th>
<th>Unit</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castle</td>
<td>11</td>
<td>1740</td>
</tr>
<tr>
<td>Mitchell</td>
<td>39</td>
<td>3151</td>
</tr>
<tr>
<td>Devonald</td>
<td>76</td>
<td>1575</td>
</tr>
<tr>
<td>Humphrys</td>
<td>110</td>
<td>1199</td>
</tr>
</tbody>
</table>

**Total** 7665 acres

**Total area of Sample** = 13,167.2 acres.

Ratio of Total Area Sampled : Frame Area = 1:8.56

Ratio of Area Sampled in Arable Stratum : Total Area of Arable Stratum = 1:14.757

Ratio of Area Sampled in Bush Stratum : Total Area of Bush Stratum = 1:4.104

The additional sample contained units 42, 99 and 41 from the Arable Stratum and 65 and 107 from the Bush Stratum. These units were not enumerated because there was not sufficient time.
DIVISION OF FIRST-STAGE SAMPLING UNITS INTO SUB-UNITS

The original scheme of subdividing the first-stage units by physical features mapped in the field was found to be impractical for three reasons:

1. In some units there were not enough features to use as boundaries.
2. In cases where features were found their use as boundaries gave units of widely differing size.
3. In sugar cane areas the use of cane traces as boundaries divided the land into sub-units which contained either all sugar cane or no sugar cane at all, thus introducing bias.

It was decided that the first-stage units should be subdivided at random into second-stage units of approximately equal size. A method was devised by the writer which divided the units into 16 sub-units and this method is described below.

The unit was first divided into two approximately equal portions by a line across the map on a selected compass bearing. Each portion was then halved by a line on a different compass bearing. This halving process was carried out four times, dividing the unit first into two portions, then four, then eight and finally sixteen sub-units. The stages in the division can be seen on the map of unit 39 (Appendix B. 3).

The procedure for selecting the compass bearings was as follows. First, 9 True compass bearings at 20 degree intervals between 20° and 180° were denoted by the numbers 1 to 9. Fifteen numbers between 1 and 9 were then read from a column in Fisher's Table of Random Combinations. The columns of numbers in the table were arranged in blocks of 9 different digits and this ensured that every digit would
be selected at least once and none of them more than twice. For unit 39 the following sequence of 15 randomly selected compass bearings was obtained.

<table>
<thead>
<tr>
<th>Sequence Number</th>
<th>Random Number</th>
<th>Compass Bearing in Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>100°</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>80°</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>180°</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>140°</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>20°</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>120°</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>160°</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>60°</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>40°</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>140°</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>180°</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>20°</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>160°</td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>120°</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>40°</td>
</tr>
</tbody>
</table>

The general procedure for subdividing the unit map can best be described by using unit 39 as an example. A tracing of the unit map was placed over graph paper and orientated so that the first of the selected compass bearings, 100°, was along an axis of the graph paper grid. By visual judgement a grid line was selected which divided the unit into two roughly equal portions. The grid squares in the two portions of the unit were counted. This count showed how nearly equal the two portions were and which way the dividing line needed to be moved to make them more nearly equal.

The northern half of the unit was now subdivided in a similar manner by a line along the second random bearing which was 80° and then the southern half was divided by a
line along a bearing of 180°. This process was repeated until the unit was divided into 16 sub-units. The sequence in which the subdivisions were made can be seen on the map of unit 39 (Appendix B.3).

The method of land use classification was devised after members of the team had studied the problem in the field. The aim was to devise a system of classification which covered all the wider uses of land and gave as much information as possible. At the same time the distinctions between the classes had to be sufficiently clear cut for the enumeration to be done by untrained personnel.

It was decided that the land should be divided into two main classes: Cultivated Land and Uncultivated Land. To be classed as Cultivated Land an area had to be under crops or else under recent crop residues. Plantation crops were classed as Cultivated Land only if the grass had been mown and if they were looked after. This rule distinguished cultivated crops from abandoned plantations.スタッフ was given the task of working out the final details of the classification. He prepared a Classification Table for the guidance of the enumerators and this table is given below with some explanatory notes added.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Class of Usage</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. S.</td>
<td>Estate Sugar Cane.</td>
<td></td>
</tr>
<tr>
<td>C. E.</td>
<td>Good Farmers' Sugar Cane.</td>
<td></td>
</tr>
<tr>
<td>C. B.</td>
<td>Bad Farmers' Sugar Cane.</td>
<td>Only if less than 50% of the total ground cover.</td>
</tr>
<tr>
<td>F.</td>
<td>Rice.</td>
<td></td>
</tr>
<tr>
<td>N.</td>
<td>Short term Food Crops, e.g., maize.</td>
<td></td>
</tr>
<tr>
<td>P.</td>
<td>Tobacco, cassava, sweet potatoes, pigeon peas, manioc, maize, vegetables, etc.</td>
<td></td>
</tr>
</tbody>
</table>
V. CLASSIFICATION OF LAND USE

The method of land use classification was discussed after members of the team had studied the problem in the field. The aim was to devise a system of classification which covered all the wider uses of land and gave as much information as possible. At the same time the distinctions between the classes had to be sufficiently clear cut for the enumeration to be done by untrained personnel.

It was decided that the land should be divided into two main classes: Cultivated Land and Uncultivated Land. To be classed as Cultivated Land an area had to be under crops or else under recent crop residues. Plantation crops were classed as Cultivated Land only if the grass had been cutlassed and if they were looked after. This rule distinguished cultivated cocoa from abandoned plantations.

Hannagan was given the task of working out the final details of the classification. He prepared a Classification Table for the guidance of the enumerators and this table is given below with some explanatory notes added.

Symbol | Class of Usage | Notes
--- | --- | ---
CULTIVATED LAND
S.E. | Estate Sugar Cane. | Cane less than 50% of the total ground cover. 
S.G. | Good Farmers' Sugar Cane. | 
S.B. | Bad Farmers' Sugar Cane. | Rest bush and weeds. 
R. | Rice. | Stools showing that rice has been grown this year. 
F. | Short term Food Crops. | Tannia, cassava, sweet potatoes, pigeon peas, plantain, maize, vegetables, etc., grown separate or mixed in areas of over 1/10 acre and excluding house gardens.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Class of Usage</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.N.</td>
<td>Coconuts.</td>
<td>In stands of over ( \frac{1}{4} ) acre.</td>
</tr>
<tr>
<td>C.</td>
<td>Citrus</td>
<td>In stands of over ( \frac{1}{4} ) acre.</td>
</tr>
<tr>
<td>Co.</td>
<td>Cocoa, bananas and coffee.</td>
<td>Separate or mixed, cutlassed and generally tended.</td>
</tr>
<tr>
<td>O.</td>
<td>Orchard Crops.</td>
<td>Cashew nuts, Tonka beans, Pineapples, etc. in stands of over ( \frac{1}{4} ) acre.</td>
</tr>
<tr>
<td>T.</td>
<td>Timber trees in pure stands.</td>
<td>Majority of vegetation over 6' in height, including bamboo and abandoned cocoa fields.</td>
</tr>
<tr>
<td>H.B.</td>
<td>High Bush.</td>
<td>Majority of vegetation under 6' in height, including bush grazing.</td>
</tr>
<tr>
<td>L.B.</td>
<td>Low Bush.</td>
<td>Only rivers over 10' wide at the top of the banks are included. Swamps must be permanently wet and contain over 50% sedges and swamp plants.</td>
</tr>
<tr>
<td>W.</td>
<td>Rivers and Swamps.</td>
<td>Main stand in grass. Includes grass traces and grass road verges. Some grazing is also obtained from land classed as low bush.</td>
</tr>
<tr>
<td>G.</td>
<td>Grazing.</td>
<td>Roads, railways, factories and isolated houselots. Villages and built up areas. Lines of houses with a density of at least 2 houses per 100 yards and including gardens of less than ( \frac{1}{4} ) acre.</td>
</tr>
<tr>
<td>N.A.</td>
<td>Non agricultural use.</td>
<td></td>
</tr>
<tr>
<td>U.</td>
<td>Urban areas.</td>
<td></td>
</tr>
</tbody>
</table>
VI. MAPPING OF SAMPLING UNITS

The possibilities of obtaining data from aerial surveys and sugar estate maps were considered.

Sugar estate maps were only available for a few of the Arable Stratum units and in some of these units only part of the unit was included in the sugar estate map. An estate map was checked in the field and found to be inaccurate and out of date. For these reasons it was decided that land use data should not be obtained from estate maps. However in some cases the estate maps were used for mapping in traces that were not shown on the Ordnance Survey map.

Aerial Survey photographs were available for units 4, 11 and 13 at a scale of approximately 1:11,000, but for the other units only small scale photographs were available. The small scale photographs which had a scale of approximately 1:45,000 failed to show cocoa plantations and traces in the forest. The large scale photographs showed most classes of land use clearly. However data were not obtained from these photographs because they were three years old and because they were not available for all the units. In some units the large scale photographs were used for mapping traces and roads and for correcting errors in the Ordnance Survey map.

The method used for mapping the units is described in the following summary:

(a) First large scale maps of the units were made by enlargement from the Ordnance Survey map. The unit boundaries and any other roads and traces shown on the Ordnance Survey map were marked on the unit map.

This was done by the unit supervisor during the Christmas term, 1954.

(b) The land use classes were then mapped in...
the field using the roads and traces already marked on the unit map as boundaries. This was done during the Christmas vacation by the team of five enumerators under the guidance of the unit supervisor.

(c) The completed unit map was then divided at random into sixteen second-stage sampling units by the method already described. The acreages of the different classes of land in each sub-unit were then measured. This work was done by the unit supervisor during the first three months of 1955.

The detailed procedure of these three stages of mapping will be considered in the following sections. After the section on field mapping will be sections describing the mapping of the two units supervised by the writer, which will be followed by a section dealing with the method of abstracting data from the completed unit map.

PREPARATION OF LARGE SCALE UNIT MAPS

The Ordnance Survey map of 1926 will be referred to as the O.S. map. The O.S. map was of a scale 1:50,000 or 1.267 inches to the mile which was too small for detailed mapping. Castle was therefore appointed to find a suitable scale for the unit maps. He selected a scale of 8 inches to the mile or 1 inch to 10 chains. The advantage of this scale was that when the unit maps were drawn on graph paper the inch squares were equal to 10 acres and the small 1/10 inch squares were equal to 1/10 acre, which simplified the measurement of acreage. The use of graph paper for the unit map also simplified field mapping because the width of a small square was 22 yards and the width of a 1 inch square was one furlong.

The O.S. map was marked with a grid of 100 chain squares. A grid of the same scale was marked on the graph paper and all details were transferred from the O.S. map to
the graph paper by plotting that position in relation to this grid. The procedure was as follows:

A point on the O.S. map was selected and its distance from the nearest vertical grid line was measured with dividers. The points of the dividers were placed on the scale at the bottom of the O.S. map and the distance read in chains. This was repeated to give the distance of the selected point from the nearest horizontal grid line. By means of these two co-ordinates the point could then be plotted onto the graph paper which had a scale of 1/10 inch square having a width of one chain.

A series of points along the centre of boundary features were plotted on the graph paper and joined together to give the boundary line. Internal roads, railways and traces were also plotted in.

As the O.S. map was out of date field reconnais­sances were carried out to check the boundary features. Additional roads and traces were also mapped and in some cases aerial photographs and estate maps were used for this purpose. The completed unit maps were then reproduced to provide field copies for the enumerators.

FIELD MAPPING

A fairly rapid method of mapping was essential because of the large area to be mapped by five enumerators in the short time available. This consideration precluded the use of plane tables and measuring chains and it was therefore decided that distance should be measured by pacing and direction by means of a hand compass.

Each unit was mapped by the team as a whole under the guidance of the unit supervisor. At first the enumerators mapped in pairs, one man measuring distances and taking bearings and the other mapping and recording. It was later found that the quickest and most satisfactory
way of mapping a unit was for each enumerator to map one section individually. The team met for lunch and tea and this enabled the enumerators to consult the supervisor about any problems of mapping or classification.

As the Bush Stratum units were larger than the Arable Stratum units and less important agriculturally they were mapped less accurately than the Arable Stratum units. Because of the different natures of the strata and the different standards of accuracy required the method of mapping varied with the strata. The detailed mapping procedure will be considered in the following two sections which describe the survey of the two units supervised by the writer.

SURVEY OF ARABLE STRATUM UNIT 15

This unit of 744 acres was a long narrow strip of land between the Caroni River and the main road from Caroni to San Raphael. The unit included Caroni village at the western end and Piarco village at the eastern end whilst the land between was intensely cultivated and mostly under estate and peasant sugar cane. It is shown in the map (Appendix B. 2).

In the Christmas term an enlarged map of the unit was made from the O.S. map by the method described.

A field reconnaissance was carried out and this showed that the course of the Caroni river differed considerably from that shown on the O.S. map. It also showed that many roads and traces existed that were not shown on the map.

As it would have been very difficult to survey the course of the river in the field it was decided that this information could best be obtained from aerial survey photographs.

The Government Survey Department was able to supply aerial photographs taken in 1952 which were of the
large scale of approximately 1:11,000 and these showed the Caroni River and the roads and traces clearly. Yates (1953) mentions that in aerial photographs the scale may vary between one photograph and another due to changes in the height of the aeroplane. The scale may also vary from the centre of the photograph to the edge because the edge is further away from the camera. Measurements showed that these effects were negligible in the case of the large scale photographs, but the latter effect was noticeable in the small scale photographs of scale 1:45,000.

The line of the south bank of the Caroni River was plotted onto the unit map from the photograph. Measurements on the photograph and in the field at several places showed that the average width of the Caroni River was 50 yards between the tops of the banks. The centre of the river formed the unit boundary and this was taken to be a line 25 yards from the bank and parallel to it and this was plotted onto the map.

The course of the river as shown in the O.S. map was found to differ by as much as 150 yards in some places from that shown on the photograph. This error in the O.S. map made the area of the unit over 50 acres larger than that obtained from the photograph. In two places bends in the river shown on the O.S. map had since been cut off to form ox bow lakes and these were plotted onto the map from the photograph. Roads and some of the main sugar cane traces were also plotted onto the unit map from the photograph.

After correcting the unit map a second reconnaissance was carried out and the quarter mile stones along the main road were mapped to act as landmarks. The problems of the unit were studied on this visit and plans for the method of surveying it were formulated.

The field survey was carried out by the team of
five during one day in the Christmas vacation, 1954. On the day selected for the survey, December 18th, the unit was found to be flooded to a depth of 3-6 feet following heavy rain the night before. The floods caused considerable damage to rice crops and made 80 people homeless in Caroni village. It was decided to postpone the survey. By December 23rd the land was dry again and the survey was completed on this day.

The unit was divided up into 5 sections by the supervisor and each enumerator was given one section to survey. As the unit was long and narrow it was easily divided into five by the traces running north-south from the main road to the river. The divisions were made so that each section would require about the same amount of time to survey (Appendix B. 2). The complicated middle section was surveyed by the supervisor and the other sections were allotted to the enumerators at random by drawing lots.

Each enumerator was given a map of his section accurately reproduced from the unit map and also a sheet of instructions on the classification system. The enumerators were instructed to use the main road forming the southern boundary as the base line for their surveying.

The enumerator first measured half the width of the boundary road and then the width of the grass verge, recording these in his notebook, and marked a line representing the outer edge of the grass verge on the map.

Next the enumerator mapped in the points where traces and land use boundaries met the main road. This was done by pacing their distance from the nearest quarter mile stone or other landmark on the unit map. He measured the width of the traces and found their direction by taking a compass bearing. Mapping to scale was made easy by the fact that the maps were on graph paper and the width of one
small square was equivalent to 22 yards. The grid of the graph paper ran true north and south and it was thus simple to plot the direction of a trace with a protractor, allowing for the magnetic variation of the compass being 9° West of True North.

Each field was measured and mapped and was labelled with a land use letter and a field number. The field number was recorded in the enumerator's field survey notebook and opposite it was entered the length and breadth of the field. Roads and traces were also numbered and the number was recorded in the notebook together with the width and the direction of the road or trace. With roads a note was made recording whether the surface was tarred, metalled or earth.

Having surveyed the land along the main road which was the southern boundary of the unit, the enumerator then proceeded to pace along one of the northward running traces mapping in the land on both sides of him. In this way a strip was surveyed from the main road to the river. The enumerator then started at the main road again and surveyed along the next northward running trace, going off on each side trace till he reached the land he had surveyed the previous time. In this way the map was systematically built up using the main road as a base line and the north-south traces as the secondary base lines. This method was found to be both rapid and accurate, though in this unit the conditions were made easier by the fact that many of the traces ran exactly north-south or east-west.

One problem encountered was the strip of bush along the river bank which was very dense and varied in width. Measurements in several places gave an average width of 15 yards and so it was mapped as being an even strip of this width except in some places where it was absent altogether
and some other places where the aerial photograph showed it to be very thick.

In the second term the enumerators' section maps were combined to give one complete unit map. The data in the field notebooks were used to make the maps more accurate. As it was impossible to draw traces strictly to scale they were all drawn 1/3 square wide (7 yards). When trace areas were required at a later stage they were obtained by calculation from the field measurements, whereas crop areas were obtained direct from the map.

SURVEY OF BUSH STRATUM UNIT 39

This unit of 3,151 acres, which was the largest unit surveyed, was situated to the west of Talparo, as shown on the Frame Map (Appendix B. 1). The land form was a dissected peneplain with Llanos sand deposits capping the hills and the clay stratum exposed in the valleys. The unit was sparsely populated. There were areas of cultivation near roads and villages and the rest of the unit was forest. The main crop was cocoa except in the north-east where there was a broad valley near Las Lomas in which sugar cane and rice were grown, as shown in the unit map (Appendix B. 3).

During the Christmas term, 1954, a large scale map of the unit was made from the O.S. map. At the time when the frame was divided into sampling units two of the team had visited the area to find a road or trace suitable for a boundary between unit 39 and the unit to the west of it. They were told by local inhabitants that Dan's Road ran from Todds Road to Las Lomas and so it was used as a boundary although it was not shown on the map. To complete the unit map it was necessary to map this road. Only small scale aerial photographs were available which did not show Dan's Road and it was therefore decided that a field survey of this road should be carried out.
Dan's Road was surveyed one day in November, 1954, by the supervisor. First the point where it joined Todds Road was mapped by pacing the distance from the nearest quarter mile stone. From this point the road was surveyed northwards using the following technique. A compass bearing was taken on the centre of the road at its furthest visible point, a distance which varied from 40 to 200 yards. The distance to this point was then paced in a straight line and both the bearing and the distance paced on this bearing were recorded in a notebook. This process was repeated until the end of the road was reached after about a mile. At this point the road joined Dan's Trace which was shown on the O.S. map, and the first part of this trace was also surveyed to check the accuracy of the method. The road was then accurately plotted onto the unit map from the data in the notebook, using a protractor in the map room. The position of a certain bridge on Dan's Trace as found by this "dead reckoning" method of survey differed by 150 yards from that shown on the O.S. map. It was considered that the inaccuracy in mapping Dan's Road was probably no greater than the inaccuracy in the mapping of the other boundary roads on the small scale O.S. map.

A further reconnaissance was carried out to check the boundaries and to study the problems of the unit. Local inhabitants were questioned in order to learn the names and locations of all the traces in the unit and also to find out which areas of the forest contained cocoa plantations.

The field survey was done by the team of five enumerators during the Christmas vacation and took 1½ days to complete. Observation had shown that all the cultivation was found near the roads and traces. The method of survey therefore was for an enumerator to proceed along a road or
trace mapping in the cultivated areas. Any side-tracks were followed as they usually led to outlying patches of cultivation. Each enumerator was given a unit map on which were shown all known traces and their names.

As there were over 20 miles of roads and traces in the unit, a plan of work was made which would reduce walking to a minimum. A further problem was that there was no motor road connecting Chin Chin road in the north of the unit with Todds road in the south and this meant using two cars and splitting the team into two parties. Two enumerators were sent in one car to survey Mahaica trace and Todds road, whilst the supervisor and the other two enumerators went to Las Lomas in the other car to survey the rest of the unit. The plan also arranged for the enumerators who were surveying Mahaica Trace and Toussaint Trace to be taken by car to one end of the trace and collected at the other end, thus saving a long walk back.

Unfortunately this plan was thwarted by an Act of God in the form of a landslide which removed part of the road north of Talparo, thus preventing the car with the two enumerators from reaching Todds Road. Rather than make a detour of about 30 miles they went along Chin Chin Road and surveyed Mahaica Trace and Phipps Trace on foot. It was therefore necessary to spend a further afternoon surveying along Todds Road and Dan's Road.

Cocoa was difficult to survey accurately because of the irregular shape of the plantations and the difficulty of walking and seeing through cocoa. The method of survey used was to pace the length of the plantation along the path. The depth of cocoa on either side of the path was found by pacing at right angles to the path, using a compass to keep in the right direction. The depth of cocoa was measured at several points along the path. In this way a series of points on the edge of the cocoa were plotted and these were
joined up to give the boundary of the plantation. In some cases where a path did not run the length of the cocoa the average length and breadth of the plantation were found and it was then mapped as a rectangle.

In this unit rivers and swamps were not recorded as it was considered that the information did not justify the effort that would have been required to obtain it.

Lastro or secondary bush developed on abandoned cultivated land was recorded as "Low Bush" when it was less than 6 foot high.

All land not surveyed was classed as "High Bush" and this may have contained some low bush and rivers and swamps. To the south-west was the 300-acre Todds Road Forest Reserve which was being worked. As there were no planted pure stands of timber trees it was classified as "High Bush" rather than "Timber".

It was impossible to map accurately the position of cocoa plantations which were far from the boundary road or any other landmark. The error involved in mapping a winding path for several hundred yards through the forest was inevitably great. However although the position of an isolated cocoa plantation might be maddened very inaccurately its size could be mapped as accurately as a cocoa plantation near a landmark. It was considered that these errors in mapping the position of isolated plantations were random and would not result in any bias in the distribution of cocoa plantations amongst the 16 sub-units.

The five enumerators' maps were combined into one complete unit map during the Easter term, 1955.

ABSTRACTION OF DATA FROM THE UNIT MAP

The total acreage of the first-stage sampling unit was found by counting the number of graph paper squares within the unit boundaries. Each of the large one inch
squares was equivalent to 10 acres and each small square was equivalent to 1/10 acre. The total acreage was found during the Christmas term before the land use classes had been mapped. When the land use boundaries had been mapped each area was marked with its class abbreviation and all the areas of the class were marked with a serial number. Thus the cocoa plantations in unit 39 were marked from Co. 1 to Co. 37.

The acreage of each area was found by adding the squares within its boundaries. Where the boundary line cut across a small square the square was counted as a whole square if more than half of it was within the area, but if less than half the square was in the area, then it was not counted at all. As each square was counted it was marked with a pencil dot, thus ensuring that no squares were omitted and none counted twice. The acreage of the area was then entered in a notebook opposite the number of the field, e.g. Co. 3. 2.6 acres. Although tedious, this method was reliable as it ensured that no small areas were omitted.

Acreages of roads, traces, grass road verges and rivers were found by calculation. The width was recorded in a notebook at the time of field mapping and the length was obtained from the map by measurement with a ruler or a map measuring-wheel. The length multiplied by the width gave the area in square yards and this was divided by 4340 on a slide-rule to give the acreage correct to 0.1 acre.

The class totals were added together to see if the total obtained was the same as that obtained for the total acreage of the unit. In the case of unit 39 this check was not carried out as the squares in the High Bush class had not been counted. The acreage of High Bush in this unit was found by subtracting the sum of the other class totals from the total acreage of the unit.

Having obtained the land use class totals for the
first-stage sampling unit, the unit was then divided into 16 sub-units as described in the section on Sampling. The class acreages for the sub-units were then found and the accuracy checked by adding them together to see that they agreed with the unit totals.

The total acreage of each land use class in each sub-unit of units 13 and 39 is shown in the tables in Appendices A. 1. and A. 2.

The following procedure was used to estimate the total acreage of each land use class in the total area of the frame. Cocoa is taken as an example.

The unit totals were added together to give the acreage of cocoa in the sample from each stratum. The sample totals were multiplied by raising factors to give the total acreage of cocoa in each sample. The raising factor used was the total acreage of the stratum divided by the acreage of the sample. The raising factor was 14.787 for the Arable Stratum and 4.1043 for the Bush Stratum. The totals for the two strata were then added together to give the estimated total acreage for the whole survey area.

Example:

| Total area of Cocoa in Bush Stratum Sample | = 676.4 acres |
|                                          | = 676.4 x 4.1043 |
|                                          | = 2764.4 acres |
| Total area of cocoa in Arable Stratum Sample | = 20.2 acres |
|                                          | = 20.2 x 14.787 |
|                                          | = 298.1 acres |
| Total acreage of cocoa in Survey area | = 3062.5 acres |

The method used for estimating the sampling error is described below. Cocoa again being taken as an example.

The sum of squares of the deviations of the sub-unit values from the stratum mean were calculated. For the
VII. ANALYSIS OF RESULTS

Humphrys was appointed to find a method of estimating the population values and the random sampling errors. He gave the assistants instructions on the method of analysis and allotted each member of the team three classes of land use to analyse. The writer was responsible for estimating the population value and sampling error for Cocoa, Orchard Crops and Non-Agricultural Use.

The following procedure was used to estimate the total acreage of each land use class in the total area of the frame. Cocoa is taken as an example.

The unit totals were added together to give the acreage of cocoa in the sample from each stratum. The sample totals were multiplied by raising factors to give the total acreage of cocoa in each sample. The raising factor used was the total acreage of the stratum divided by the acreage of the sample. The raising factor was 14.757 for the Arable Stratum and 4.1045 for the Bush Stratum. The totals for the two strata were then added together to give the estimated total acreage for the whole survey area.

Example:

Total area of Cocoa in Bush Stratum Sample = 678.4 acres
Total = 678.4 x 4.1043 = 2784.4 acres.

Total area of Cocoa in Arable Stratum Sample = 20.2 acres
Total = 20.2 x 14.757 = 298.1 acres.

Total acreage of cocoa in Survey area = 3082.5 acres.

The method used for estimating the sampling error is described below, Cocoa again being taken as an example.

The sums of squares of the deviations of the sub-unit values from the stratum mean were calculated. For the
Bush Stratum this was done by summing the squares of the 64 sub-unit cocoa acreages and subtracting a correction factor consisting of the square of the grand total divided by the number of values in that total, which was 64.

The corrected sum of squares value was then divided by the number of degrees of freedom, which was n-1 or 63 for the Bush Stratum. This gave the within-strata variance $S_i^2$.

This value $S_i^2$ was multiplied by $ni(1-f_i)$ where $f_i$ was the sampling fraction. For the Bush Stratum, $f_i = 1$ in 4.103. The value obtained was equivalent to $V(S_i(y))$, where $V = the variance, y = estimated unit value of the stratum and $S_i = summation for the stratum$.

This value was then multiplied by $g^2$ to give $V(Y_i)$ where $Y_i = estimated value for the stratum, g = \frac{1}{f_i}$ and therefore $g$ is the raising factor already mentioned. For the Bush Stratum $g = 4.103$.

This procedure was then repeated to give an estimate of $V(Y_i)$ for the Arable Stratum. For the Arable Stratum the following constants were used:

\[
\begin{align*}
n &= 96 \\
f_i &= 1 \text{ in } 14.757 \\
g_i &= 14.757.
\end{align*}
\]

The values of $V(Y_i)$ for the two strata were added together to give $V(Y)$ the variance of estimated population value for the survey area.

The Standard sampling error was equal to the square root of the variance of the estimated total population value, i.e. $S.E. = \sqrt{V(Y)}$.

The method is demonstrated numerically below where the sampling error of the total cocoa population estimate is calculated.
For the Bush Stratum:-

Sum of Deviations = Sum of squares - Correction factor

\[ \text{Sum of Deviations} = 24619.96 - \frac{678.4^2}{64} \]

\[ = 17,428.92 \]

\[ \text{Si}^2 = \frac{\text{Corrected sum of squares}}{\text{Degrees of freedom}} \]

\[ = \frac{17,428.92}{63} \]

\[ = 276.65. \]

\[ V \text{Si}(Yi) = Si^2 \times n_i(1-f_i) \]

\[ = 276.65 \times 64 \times (1 - \frac{1}{4.103}) \]

\[ = 13,385.43. \]

\[ V(Yi) = V\{\text{Si}(Yi)\} \times g_i^2 \]

\[ = 13,385.43 \times 4.103^2 \]

\[ = 230,738.04. \]

For the Arable Stratum:

Corrected sum of squares = 350.82 - 408.04

\[ = 346.57 \]

\[ \text{Si}^2 = \frac{346.57}{95} \]

\[ = 3.643 \]

\[ V\{\text{Si}(Yi)\} = 3.643 \times 96(1 - \frac{1}{14.757}) \]

\[ = 326.39 \]

\[ V(Yi) = 326.39 \times 14.757^2 \]

\[ = 71,077.95 \]

\[ V(Y) = 230,738.04 + 71,077.95 \]

\[ = 301,815.99 \]

\[ \text{Variance of estimated population value } V(Y) = 301,815.99 \]

\[ \text{S.E.} = \sqrt{301,815.99} \]
Standard Sampling Error $S.E. = 549.3$ acres.

Percentage Sampling Error for Cocoa

\[
\frac{549.3}{3082.5} \times 100 = 17.8\%
\]

The population estimates and sampling errors for Orchard Crops and Non-Agricultural Use were worked out in a similar manner. The estimates obtained and the sampling errors are shown in the following table.

<table>
<thead>
<tr>
<th>Land Use Class</th>
<th>Acreage</th>
<th>Percentage Sampling Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.E. Estate Sugar Cane</td>
<td>38,660</td>
<td>9.4</td>
</tr>
<tr>
<td>S.G. Farmers' Cane- Good</td>
<td>7,385</td>
<td>63.6</td>
</tr>
<tr>
<td>S.B. &quot;- Bad</td>
<td>1,114</td>
<td>23.8</td>
</tr>
<tr>
<td>R. Rice</td>
<td>3,783</td>
<td>21.8</td>
</tr>
<tr>
<td>F. Food Crops</td>
<td>2,309</td>
<td>17.2</td>
</tr>
<tr>
<td>C. Citrus</td>
<td>1,141</td>
<td>30.9</td>
</tr>
<tr>
<td>CN. Coconuts</td>
<td>22</td>
<td>97.6</td>
</tr>
<tr>
<td>Co. Cocoa</td>
<td>3,083</td>
<td>17.8</td>
</tr>
<tr>
<td>O. Orchard Crops</td>
<td>242</td>
<td>33.0</td>
</tr>
<tr>
<td>G. Grass</td>
<td>7,400</td>
<td>9.8</td>
</tr>
<tr>
<td>L.B. Low Bush</td>
<td>4,914</td>
<td>21.5</td>
</tr>
<tr>
<td>H.B. High Bush</td>
<td>36,965</td>
<td>12.0</td>
</tr>
<tr>
<td>W. Rivers and Swamps</td>
<td>1,479</td>
<td>20.9</td>
</tr>
<tr>
<td>U. Urban</td>
<td>3,168</td>
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</tr>
<tr>
<td>N.A. Non-Agricultural Use</td>
<td>972</td>
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<tr>
<td>T. Timber</td>
<td>7</td>
<td>218.0</td>
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<tr>
<td><strong>Total acreage</strong></td>
<td><strong>112,645</strong></td>
<td></td>
</tr>
</tbody>
</table>
VIII. CONCLUSIONS

The writer considers that one object of the project was achieved successfully. The project gave all members of the team valuable experience of survey methods and the practical problems of applying the methods.

The main object of the survey was only partially achieved. Much useful information was obtained on the problems of carrying out a survey of this nature under local conditions and the experience gained should enable a satisfactory method to be designed for any future surveys. However as the estimates obtained were subject to a high degree of random sampling error it cannot be claimed that the method of survey was entirely satisfactory. In the following paragraphs the various sections of the survey will be discussed.

The use of a map as the frame proved satisfactory and it is considered that it was the best type of frame that could be used within the limitations set on the choice of frame.

The use of physical features for dividing the map into first-stage sampling units was found to be satisfactory. The random method of dividing the first-stage sampling units into second-stage units was also satisfactory.

That the sampling method was unsatisfactory is shown by the fact that although a fairly high sampling fraction was taken, the random sampling error was high. The extreme variability of the units in the Arable Stratum with regard to land use was not fully appreciated and the sampling procedure adopted was therefore unsuitable. There were too few first-stage sampling units and these units were too variable in size. Recommendations will be made suggesting how these faults could be avoided by minor modifications of the sampling method.
The classification system was found to be satisfactory. It covered all cases of land use and the distinctions between classes were simple to determine in the field.

The method of field enumeration by mapping was found to be satisfactory in most of the Arable Stratum. The method was slow and tedious in areas containing a complex patchwork of peasant holdings. In these complex areas a high degree of mapping ability was required and the method is therefore not suitable for untrained enumerators. In the Bush Stratum the method was not satisfactory for mapping cocoa plantations. The cocoa plantations had complex shapes and the paths through them were very tortuous, thus making mapping slow and inaccurate. Possible alternatives to this method of enumeration will be considered in the section on Recommendations.

In judging the results of this survey it must be borne in mind that a survey of this scale was an ambitious undertaking considering the limited time and facilities available. No survey of a similar nature had been attempted before and so this survey was essentially experimental. The field mapping was of necessity rather hasty and inaccurate in the Bush Stratum. The writer considers that with a few small modifications the method used can yield as accurate results as can possibly be obtained with the limited resources available.
The writer considers that the method of survey used could be improved by the following modifications.

The design of the sampling method should be altered in order to reduce the random sampling errors. The number of first-stage units in the frame should be increased from 110 to at least 250 units using physical features as boundaries. Any exceptionally large units should be subdivided. In this way a population of smaller units would be obtained which were less variable in size.

In all the units mapped during the survey, roads and traces were found which could have been used to divide the units into smaller areas. Roads and traces not shown on the Ordinance Survey map could be found by more field reconnaissance and by using Ward maps, Aerial Survey photographs and sugar estate maps. The first-stage units obtained should be stratified into three strata: a Bush Stratum, an Estate Sugar Cane Stratum and an Arable Stratum. This recommendation is based on research done by Humphrys who found that the use of the three strata suggested would give lower sampling errors for sugar cane and some other crops. With the greater number of units stratification by size would also be possible if required. With this improved frame the method of sampling used, namely a 10% first-stage sample and a 100% second-stage sample, should give a lower sampling error.

The field survey should be carried out after March. At this time of year the weather is usually dry, thus making field work easier. Most of the sugar cane is harvested by this time of year and this would simplify the field work.

A line method of survey could be carried out in peasant sugar cane areas as a possible alternative to mapping. It is considered that in the areas of cocoa and forest a line survey method of enumeration would be better than the mapping.
method. It would entail hiring junior staff to cut paths through the forest but it is considered that the expense would be justified.

If at some future date a Land Use Survey is undertaken which is regarded as practical rather than experimental, then the restrictions applied to this survey should be removed as far as possible. Money for hiring assistants should be provided and the fullest use of Ward Maps and Aerial Survey Photographs should be permitted.

In the areas for which they are available the large scale Aerial Survey photographs could be used as the frame for either a line or an area survey. With a stereoscope it would be possible to enumerate the land use data from the photograph. Field work could be reduced to checking areas, shown on the photograph, of which the land use was uncertain. The photographs were taken in 1952 and so, although the field boundaries would mostly be accurate, the cropping would be largely out of date.
X. SUMMARY

An experimental Land Use Sample Survey was carried out on an area of 176 square miles in the Northern Plain of Trinidad.

A map was used as the frame with the units being defined by physical features. The units were stratified into two land use strata, and a first-stage sample of 1 in 11 and a second-stage sample of 100% were taken.

Information required was the acreage of land under each of 16 classes of land use. Enumeration of data was done by making a land use map of each unit in the sample.

The estimates obtained were unreliable because of high random sampling errors.

Recommendations for the improvement of the method of survey are made.
XI. REFERENCES

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Land Productivity Map of Trinidad. B.W.I.
Government of Trinidad.


Yates, F. 1953.
Sampling Methods for Censuses and Surveys.
Charles Griffin and Co. London.

Plan for a World Census of Agriculture.
### ARABLE STRATUM UNIT 13

#### Acreages of Land Use Classes in the Sub-units

<table>
<thead>
<tr>
<th>Sub-Unit</th>
<th>Estate Sugar cane</th>
<th>Farmers' Cane</th>
<th>Rice</th>
<th>Food Crops</th>
<th>Citrus</th>
<th>Grass</th>
<th>Low Bush</th>
<th>High Bush</th>
<th>Water</th>
<th>Urban</th>
<th>Non-Agric. Use</th>
<th>Total</th>
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<td>57.5</td>
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</tr>
</tbody>
</table>

The following classes of land use did not occur:

- **CN.** Coconuts.
- **O.** Orchard Crops.
- **Co.** Cocoa.
- **T.** Timber.

Areas of roads: Pitched Roads 4.4 acres.

Metalled Roads 0.9 acre.
### APPENDIX A.2.  
### BUSH STRATUM UNIT 39  
### Acreages of Land Use Classes in the Sub-units

<table>
<thead>
<tr>
<th>Sub-Unit</th>
<th>Farmers' Sugar cane</th>
<th>Rice</th>
<th>Food Crops</th>
<th>Cocoa</th>
<th>Citrus</th>
<th>Orchard Crops</th>
<th>Grass</th>
<th>Low Bush</th>
<th>High Bush</th>
<th>Urban</th>
<th>Non-Agric. Use</th>
<th>Total</th>
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</thead>
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<tr>
<td></td>
<td>Good</td>
<td>Bad</td>
<td>R.</td>
<td>F.</td>
<td>Co.</td>
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<td>-</td>
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W. Rivers and Swamps were not enumerated. They were included in the High Bush class.

The following classes of land use did not occur:-

- S.E. Estate Sugar cane.
- C.N. Coconuts.
- T. Timber.

Areas of roads:-
- Pitched Roads 2.7 acres.
- Metalled Roads 1.7 acres.