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undertaking a sample survey. The main problem this year was to improve the accuracy of the previous survey (see A. R. Humphrys, P. S. Castle, P. Devonald, R. N. Mitchell, R. J. Hannagan); with this objective the present team was permitted to concentrate on only one strata of the whole area and to use previous data and other means for their final estimate as explained in this report. The comparison of accuracy was at one stage of the work confused by the discovery that incorrect calculation of sampling errors had been made last year and these had to be recalculated. The team was free to choose their method of sampling but was required to make a critical appraisal of its efficiency and applicability.

SUPERVISOR'S NOTE.

This report is one of four by a second team undertaking a sample survey. The main problem this year was to improve the accuracy of the previous survey (see A. R. Humphrys, P.S. Castle, P. Devonald, H.W. Mitchell, M. J. Hannagan); with this objective the present team was permitted to concentrate on only one strata of the whole area and to use previous data and other means for their final estimates as explained in this report. The comparison of accuracy was at one stage of the work confused by the discovery that incorrect calculation of sampling errors had been made last year and these had to be recalculated. The team was free to choose their method of sampling but was required to make a critical appraisal of its efficiency and applicability.

- 1) The population is too large to handle economically.
- 2) Measurements are too expensive to carry out on a large population. This happens with many drugs or vaccine which is expensive to produce. The performance of the new product is gauged by the reaction of a sample of the population.
- 3) Information is wanted quickly. Pre-estimated population estimates are wanted quickly so that the method of dealing with the surveyed area can be planned.
- 4) The population is constantly changing. A full economic survey merely gives average figures over the period of the survey, but a sample survey gives precise information at a given time, which is more useful.

INTRODUCTION.

A survey of existing land usage is the essential preliminary to the agricultural development of an area. The basic statistics of present agriculture are necessary to guide the planning and implementation of policy in an area (Douglas & Tennant 1952). The level of prospective food supply and hence the human carrying capacity of the area can be calculated from land utilization data. The acreage under cash crops is also obtained. The pattern of land utilization is often governed by soil so the utilization survey helps the soil surveyor. When the data of utilization, soil and climate have been obtained the agricultural potentialities of the area can soon be judged. The cost of surveying the whole of such areas is prohibitive, even if the staff were available, hence it is usual to employ a sample method of surveying.

Sampling may be defined as the selection of part of an aggregate of material to represent the whole aggregate. This procedure has to be adopted when:-

- 1) The population is too large to handle economically.
- 2) Measurements are too expensive to carry out on a large population. This happens with a new drug or vaccine which is expensive to produce. The performance of the new product is gauged by the reaction of a sample of the population.
- 3) Information is wanted quickly. Pre-harvest crop estimates are wanted quickly so that the method of dealing with the harvested crop can be planned.
- 4) The population is constantly changing. A full economic survey merely gives average figures over the period of the survey, but a sample survey gives precise information at a given time, which is more useful.

5). .../

- 5) The process of obtaining data leads to the destruction of the material concerned. This happens in chemical analysis.

The application of sampling is therefore universal and has many other uses beside land utilization surveys. The land utilization survey described in this dissertation is therefore an exercise in sampling as well as surveying techniques.

A sample survey has other advantages over a complete census:-

- a) Less time and expense.
- b) Number of staff required is smaller so closer supervision is obtained and the enumeration should therefore be more accurate.
- c) It can be designed to give more detailed information. The peasant surveys carried out by the College, though statistically acceptable sampling methods were not used, show the wealth of information which can be obtained.
- d) The reduced volume of material to be handled give a higher quality of abstraction and analysis.
- e) At the close of the work the statistician can state that the results are correct within an error $\pm x\%$ but no such statement can be made in the case of a full census.

The intensity of sampling is usually decided by the labour, materials and finance at the disposal of the survey organiser and the use which is to be made of the survey data. If critical calculations are being made from the survey data then the estimates have to be obtained with low sampling errors. As the accuracy of a survey increases so usually does the cost. Other... /

Other factors influencing the intensity of sampling are the stage of development of the area, its size, topographical features, natural vegetation and agricultural crops.

The main object of this survey was to find the best sampling methods and surveying techniques for an area like the Western Plain of Trinidad. Due to the limited time available certain restrictions were imposed by the Supervisor. The area was restricted to the part of the Colony that was most easily accessible and a frame which involved finding and interviewing people could not be used. As last year, the simplest equipment and standard maps were used, no outside labour was used at all.

Last year's technique of mapping certain sample areas proved satisfactory for the bush stratum since the area showed little variation. The cane arable stratum proved to be very variable and was the main cause of the high standard errors of last year's crop estimates. It was therefore decided at the outset that this year's efforts should be concentrated at lowering the standard errors of the cane arable stratum crop estimates. The means by which it was hoped to improve the accuracy of the survey are described in Chapter iv.

The survey team consisted of four post-graduate Students under the guidance of Dr. A. L. Jolly, the project tutor, who took the chair at meetings held at the planning stage. The survey was planned during term-time and most of the field work was carried out in the Christmas vacation. At the planning stage each person was, as far as possible, responsible for a certain task being carried out. In the field each member in turn supervised the survey of certain lines. When the results were calculated, each member was responsible for the calculation of certain crops. Hence every member of the team has acted as supervisor in the field and has become acquainted with the methods of calculation of the results.

I. THE AREA....

I. THE AREA.

The Southern and Eastern areas of the island could not be surveyed because of the short time available for field work. The area was limited to that of agricultural importance so Port-of-Spain and the Eastern Main Road area was not included. The Northern Range was excluded because it would have been expensive in time and money. The area chosen was therefore the same as last year.

The area was approximately rectangular in shape, bounded by the Churchill-Roosevelt Highway in the North; the Princess Margaret Highway, Madame Espagnole river and the coast line as far as the mouth of the Couva river to the West; the road through Couva, Gran Couva, Flanagin Town and Mamural to the South and the road from Mamural through Mundo Nuevo, Talparo, Brazil, San Rafael and Guanapo to the east.

The bush stratum was satisfactorily surveyed last year so all this year's field work was carried out in the cane arable stratum of last year. The boundary of the cane arable stratum is the same as that of the whole area apart from the Eastern boundary which runs from the Churchill-Roosevelt Highway down the Mausica road to the ferry then along the Caroni and Arena rivers to the Caroni road and to Las Lomas via Las Lomas road No.2. The Eastern boundary of the cane arable stratum then runs Southwards via a track to Ravine Sable road to Todd's Road, then along Freeport Todd's road and the Mission road to the Couva Main road which is the Southern boundary.

The bush stratum area is 31,459 acres and the cane arable stratum 81,186 acres, making the total acreage 112,645 acres. About two thirds of the whole area is less than 100 ft. above sea level. Higher land occurs in the South-east of the area which is the Northern face of the Montserrat hills. The highest point in the area is 582 ft. above sea level which is near Pepper Village.

The,.../

The rainfall varies from 40 inches in the Western coastal strip with a dry season of 4 - 6 months, to 70 inches in the east and a dry season of only one month.

The soil is mostly humic gley with impeded drainage and a low productivity, changing to non-calcareous perched gleys with increase in altitude. There are patches of alluvial soils and various podzols having medium to low productivity. There is a small pocket of brown forest soil of high productivity at Pepper Village.

The original vegetation of the area consisted of a broad coastal strip of marsh forest, deciduous seasonal forest down the middle of the area, and a semi-evergreen merging into evergreen seasonal forest in the east of the area. The vegetation at the time of surveying was high almost everywhere. The cane fields and the flatness of the land made it difficult to see any great distance. The area would have been much easier to survey during the dry season when most of the cane would have been harvested and walking conditions much drier.

II. THE FRAME..../

A list of villages would also be unsatisfactory as a frame since their boundaries are ill defined. It would be very difficult assigning each piece of cropped land to a particular village. A list of tribes can be used as a frame in many countries but no tribal system exists in Trinidad.

The main disadvantage of all these frames was that they involved finding and interviewing people which is a lengthy process. The team only had the Christmas vacation available for field work so a frame had to be found which would not involve personal contact with the local inhabitants. It...

II. THE FRAME.

If material is to be sampled in an accurate and unbiased manner a complete, up-to-date frame has to be available. The random or systematic samples are selected from the frame. An ideal frame may be defined as an up-to-date, complete and accurate inventory of some feature of the population surveyed. It includes every unit and therefore gives the possibility of selection to any or every individual. In sampling human populations a list of households and their members or the electoral roll would be a satisfactory frame though the latter would be little use if suffrage were not universal. In areas where a satisfactory frame cannot be found the construction of a frame may well take a major part of the time taken for the survey.

The latest census was carried out in Trinidad in 1946 so if this were used farmers who started farming after 1946 would be omitted. Much work would therefore have to be done in bringing it up to date. A complete list of farms or farmers does not exist in Trinidad, though lists of cocoa, citrus and coconut farmers who market through the various organisations were available. These were of little use since the survey was of all types of land utilization.

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It was therefore decided, as last year, to use the map of the area as the frame. The map used was the 1926 official Government Map of Trinidad with a scale 1 : 50,000 or 1.27 inches to one mile. Last year's team plotted the Churchill-Roosevelt and Princess Margaret Highways on the maps together with some of the inaccuracies which they found in their sample areas. Many more inaccuracies were found in the field this year but in spite of this the map was the most suitable frame, bearing in mind the limitations imposed on the team.

being mainly bush and plantation areas. The units of the latter type were usually larger than the former because of the lack of features which could be used as boundaries. The sampling units were therefore grouped into two strata called the "open arable" and the "bush stratum". There were 52 units in the open arable stratum and 18 in the bush stratum. Six open arable stratum units and four bush units were selected at random and surveyed. The sampling fraction in the open arable stratum was 1 : 14.73 and 1 : 4.50 in the bush stratum. The survey of the sample units involved making a area map of the units and finding the acreages of various crops from the maps. The sampling errors were calculated and were found to be very high e.g. estate cane (8.3, 41.7%, rice (2) 30.7%. A method was therefore devised to increase the number of units. This was done by employing two stage sampling with 10% sampling at the second stage. The first stage samples were divided at random into 10 sub-units to give a total of 100 sub-units. This sub-division apparently reduced the standard errors considerably. The sampling errors for estate cane and rice with 100 sub-units were 10.0% and 21.0% respectively.

Last year's team had thought that the estimates of the bush area would be less accurate than those of the open arable area because of the rough vegetation, terrain and larger sized units of the former. It was found that the estimates of the bush area were in fact more accurate than those of the open arable area.

III. LAST YEAR'S SURVEY.

Last year the area was split into units which could be defined by features shown on the map and readily identifiable on the ground. The boundaries used were mainly rivers, roads and railways. This divided the area into 110 units whose size varied from 320 to 6,400 acres. The units to the North and West of the area tended to be on flat land and the agriculture was mainly sugar cane and other arable crops. The units to the South and East were on more hilly undulating land, the vegetation being mainly bush and plantation crops. The units of the latter type were usually larger than the former because of the lack of features which could be used as boundaries. The Sampling units were therefore grouped into two strata called the "cane arable" and the "bush stratum". There were 92 units in the cane arable stratum and 18 in the bush stratum. Six cane arable stratum units and four bush units were selected at random and surveyed. The sampling fraction in the cane arable stratum was 1 : 14.76 and 1 : 4.10 in the bush stratum. The survey of the sample units involved making a crop map of the units and finding the acreages of various crops from the maps. The sampling errors were calculated and were found to be very high e.g. estate cane (S.E.) 41.7%, rice (R) 50.7%. A method was therefore devised to increase the number of units. This was done by employing two stage sampling with 100% sampling at the second stage. The first stage samples were divided at random into 16 sub-units to give a total of 160 sub-units. This sub-division apparently reduced the standard errors considerably. The sampling errors for estate cane and rice with 160 sub-units were 10.0% and 21.8% respectively.

Last year's team had thought that the estimates of the bush area would be less accurate than those of the cane arable area because of the rough vegetation, terrain and larger sized units of the former. It...../

It was for this reason that the bush sampling fraction was so much higher than that of the cane arable stratum. In practice however it was found that the content of the bush units did not vary greatly and were in fact over sampled at the expense of the cane arable stratum which was very variable. The cane arable stratum was responsible for the high standard errors of the total crop estimates. It was therefore decided by this year's team that the bush stratum had been adequately surveyed last year and this year's efforts would have to be concentrated on reducing the errors of the cane arable stratum.

IV. SAMPLING..../

CROP	SYMBOL	Percentage Sampling Errors	
		2 Strata	3 Strata
Estate Cane	SE	10.0	5.0
Rice	R	21.0	10.0
Grazing	G	8.0	3.0
Cocoa	Co	17.0	5.0
Good Farmer's Cane	SG	63.0	15.0
Bad Farmer's Cane	SB	23.0	10.0
Garden crops	C	33.0	10.0
Urban	U	20.0	17.0
Water	W	20.0	24.0
Food crops	F	17.0	10.0
High bush	HB	12.0	8.0
Citrus	C	30.0	20.0
	MEAN	23.5	17.2

The increased stratification is therefore justified even with as few units in the estate cane stratum. It..../

IV. SAMPLING METHODS.

(1) STRATIFICATION.

Humphries (1955 A) had shown that the sampling errors of estate cane and rice were reduced by further stratification of his cane arable stratum. Sample unit 4 contained 91.7% estate cane, unit 56 92.2%, and unit 71 55.5% estate cane and thus differed significantly from the other three units. The new stratum of units 4, 56 and 71 was called the estate cane stratum and the remaining units 13, 52 and 49 were called the arable stratum. The present writer calculated the sampling error of other crops using three strata instead of two. In almost every case the sampling error was less than last year's figures.

CROP	SYMBOL	Percentage Sampling Errors	
		2 Strata	3 Strata
Estate Cane	SE	10.0	5.6
Rice	R	21.8	18.0
Grazing	G	9.8	8.6
Cocoa	Co	17.8	8.9
Good Farmer's Cane	SG	63.6	16.5
Bad Farmer's Cane	SB	23.8	22.3
Orchard crops	O	33.3	32.3
Urban	U	20.8	17.3
Water	W	20.9	24.4
Food crops	F	17.2	15.0
High bush	HB	12.0	8.4
Citrus	C	30.9	29.2
	MEAN	23.5	17.2

The increased stratification is therefore justified even with so few units in the estate cane stratum. It..../

It was therefore decided to split last year's cane arable stratum into an estate cane stratum and an arable stratum. The total acreage of the estate cane stratum and its content was obtained from estate maps. The details of how this was done are outlined in Chapter VI.

(11) COMPARISON OF MAPPING AND LINE SURVEYING.

The problem remained to find an improved method of sample surveying the remainder of last year's cane arable stratum. The acreage remaining after the sugar estates had been removed was called the arable stratum. Last year's team were unsuccessful because insufficient land was sample surveyed in the cane arable stratum. The results would probably have been improved if the number of first stage units had been increased and the number of second stage units decreased. This could have been done without increasing the acreage to be surveyed if the number of first stage units were increased by making them more uniform in size. Sample unit boundaries would have to be found and mapped so that the number of first stage units could be increased. The existence of many possible boundaries which were not shown on the ordnance survey map were reported by last year's team. A certain number of these first stage units would have to be divided into second stage units which could be recognised in the field. Last year the division into second stage units was done in the office because sampling was 100% at the second stage. The refinement of last year's method would therefore involve much mapping before the field surveying was started. It was therefore decided to investigate the possibility of line surveying. The line method could be used to cover the whole area and appeared to be quicker than mapping.

The team investigated the accuracy of their pacing and the possibility of walking on an accurate bearing with the compasses available. This.../

This being satisfactory they went into the field to test their accuracy of pacing and of walking on a compass bearing. The areas used were those which were mapped last year, namely units 49, 52 and 71. The lines were also laid down in these units to see if line sampling gave reasonable sampling errors. The team worked in pairs and found that they could keep on a compass bearing though it often involved walking parallel to the line rather than actually on it. This did not matter as long as the crop which was on the line could be clearly seen and recorded.

The units varied in size so the number of lines in each unit was varied accordingly. Unit 52 being 1,320 acres had 6 lines put into it; unit 71 of 719 acres had 4 lines and unit 49 of 536 acres had 3 lines. The lines were 1,100 yards long apart from those in unit 49, which was triangular in shape so 1,100 yard lines would have overlapped. Three lines of 550 yards were used in unit 49 and their content doubled to make a total of 13 lines, each of 1,100 yards. This length of line was used because a map grid square was 2,200 square yards. At this stage it was thought that if line sampling proved to be better than mapping a number of grid squares would be selected at random and their content estimated by dropping a number of parallel lines into the square from opposite sides. To avoid overlap or large unsurveyed areas the lines would be 1,100 yards. The lines were laid down systematically to get maximum coverage of the sample units. After seven of the lines had been surveyed the field difficulties were appreciated. The method of line surveying seemed to be more accurate than last year's mapping in that it found many crops which were too small to map. There seemed little point in walking all the lines once the advantages and limitations of line surveying had been realised. The remaining six lines therefore had their contents taken from last year's crop maps.

Bearing..../

Bearing in mind the time taken to survey seven lines, it was estimated that the team could survey 100 lines of 1,100 yards each in the Christmas vacation which was the only time available for field work. The percentage sampling error was calculated for each crop from the data collected, assuming that 100 were surveyed instead of 13. The method of calculation and the content of the 13 lines are in the appendix. The 1,100 yard lines were also split into two and sampling errors calculated using 100 and 200 lines of 550 yards each.

CROP	1954/55 Survey	Pilot investigation 1955/56		
	% S.E. Arable stratum (96 sub-units).	% S.E. 100 lines of 1,100 yards	% S.E. 100 lines of 550 yards	% S.E. 200 lines of 550 yards.
SG	70.8	19.2	14.3	10.1
SB	36.2	38.8	35.5	24.5
C	38.8	22.6	27.2	15.6
F	20.7	15.6	21.0	14.9
HB	22.2	14.7	25.4	18.0
W	67.8	16.5	23.5	16.5
NA	16.6	10.9	16.4	11.6
G	17.0	13.4	16.8	11.9
R	37.4	20.4	28.2	19.9
O	36.8	26.5	37.1	26.2
U	20.6	18.6	26.1	18.4
LB	24.5	22.1	29.7	21.0

From the calculations it can be seen that last year's sampling errors would be considerably reduced by line sampling. There was a reduction in the sampling error of every crop except bad farmer's cane. The best reductions being made with good farmer's cane and low bush which were very high last year. 100 lines of 550 yards were not as good as 100 lines of 1,100 yards. There.../

There seemed little to choose between 200 lines of 550 yards and 100 lines of 1,100 yards. The latter line would be better because of the smaller number of lines which would have to be found and the volume of results to handle would be smaller. It was therefore decided that this year's team would use the line method of surveying.

(iii) GRID SAMPLING.

The possibility of dividing the map into rectangles and mapping those selected for sampling was rejected last year because of the difficulty of accurately identifying the rectangle on the ground. This year it was thought initially that lines could have been used to obtain the content of a selected number of grid squares, but the difficulty of finding the grid square and then the line within the grid square would have been too difficult. Such estimates are often biased due to enumerators taking their samples near to the route of approach. Point sampling suffers from the same disadvantages. Grid or point sampling are only useful when large scale detailed maps are available.

(iv) MULTISTAGE SAMPLING.

The difficulty of finding a large number of short lines made the team decide to use a smaller number of long lines which would mean less time wasted in actually finding lines. It was also thought that longer lines could be more accurately surveyed because check points could be used to ensure that the team were moving on the correct line. A large number of short lines would probably be a long way from the nearest check point. It was therefore decided to use long lines as first stage units and to 100% sample these at the second stage as in last year's survey.

The thirteen east-west grid lines on the ordnance survey map were used as first stage units and these were split into 1,000 yard lengths for second stage units. No first stage unit divided up exactly into second stage units so to avoid wastage of data the first stage units were written in a continuous line. The .../

The eastern end of the first line was made to run into the eastern end of line two while the west of line two ran into the west of line three and so on. There were 105 lines of 1,000 yards each.

(v) MULTIPHASE SAMPLING.

This method of sampling was not used by the team but is mentioned for the sake of completeness, and as a method which could have been used if there had been more time at the disposal of the team. When certain items of information are collected from the whole of the units of a sample and other information from only some of these units, the latter units being a sub-sample of the original, it is termed two phase sampling. Of course further phases may be added. It is a very useful method when the number of units needed to give the required accuracy on different items is widely different or the accuracy required may be widely different.

In this survey the first phase information would have been estimation of crop acreages and the second phase could have been an estimation of crop yields or some information on the cattle population. The latter would have been difficult to collect because cattle are kept in different places at different times of the day. Supplementary information of this nature was not collected this year because the team were concentrating on improving last year's sampling errors.

(vi) RANDOM AND SYSTEMATIC SAMPLING.

In a random sample every unit in the population has an equal chance of being included in the sample and each sampling unit is selected independently of the other sampling units. If the sample contains a reasonable number of units and is drawn completely at random from the population then the variation of the sample is equal to the variation over the whole area. This allows the sampling error of the property which has been estimated, to be obtained so that the accuracy of every estimate can be expressed within certain limits. For /

For example, last year, the estimated acreage of estate cane was 38,664 acres $\pm$ 3,872 acres which was a sampling error of 10.0% of the estimated total.

Yates (1953 A) distinguishes two types of sampling error, those due to bias and those due to chance differences between members of the population included in the sample and those not included. The aggregate of the former is termed the error due to bias and the latter is the random sampling error. Bias forms a constant component of error, which does not decrease in a large population as the number in the sample increases. Random sampling error on the other hand decreases as the size of sample increases. It can also be reduced by increasing the sampling fraction and by stratification.

Faulty selection of the sample may give rise to bias. This happens when there is deliberate selection of a "representative" sample or when the selection procedure is haphazard. There can be conscious or unconscious bias in the selection if the investigator allows his desire to obtain a certain result to influence his selection. The simplest method of avoiding bias in the selection process is for the sample to be drawn at random by a process like the drawing of lots or using a table of random numbers. Biased estimates are also obtained if some of the randomly selected sample units are not surveyed. This can happen in a house-to-house survey if no one is at home and the enumerator either substitutes another convenient house or makes no attempt at a second visit. Faulty demarcation of sampling units can give rise to bias. Sample areas should not be too small since errors in the demarcation of boundaries become more important as the size of unit is decreased. Biases of very small areas are often due to inclusion of border plants. Bias is permissible in certain cases however, for example, in censuses which are repeated at frequent intervals, interest is focussed on changes rather than absolute values and in such cases bias is permissible provided it remains reasonably constant.

Material which is continuously distributed either in space or time is usually sampled by taking sampling units at equal intervals over the material. This is called systematic sampling. It cannot be used if the material has any periodic features. The arable stratum did not have any properties which were periodic; the crops appeared to be scattered over the area at random. It was therefore decided to carry out a systematic line survey. Lines laid down completely at random in the area would have involved much unproductive walking and in many instances the lines would have been very difficult to find.

No fully valid estimate of the sampling error of a systematic sample is possible since the units are not allocated at random within the strata. The material is usually arbitrarily divided into strata and the sampling error calculated as if the units were selected at random from these strata. In systematic line sampling the strata are taken to contain pairs of successive units. This year's results were from the arable stratum, so sub-strata were taken to contain pairs of successive units and the error variance estimated from differences between the members of the pairs. Each difference contributes one degree of freedom. If the differences are called d and there are n' such differences, then error variance per unit = $S^2 = \frac{1}{2} \frac{S(d^2)}{n'}$. All the lines were the same length so no covariance adjustment was necessary for varying length of line.

V. .../

V, CLASSIFICATION.

Last year's classification worked satisfactorily and this year's survey was merely the further survey of part of last year's area, so little change was made in the classification. Some change was necessary however due to the different method of surveying.

It was decided to place all the timber in the high bush category because only 1.6 acres were found last year giving an error of 218%. The classification of coconuts, orchard crops and citrus was altered slightly because of the many groups of trees which occurred in stands of less than half an acre. If groups or parts of groups of six or more fell on the line, they were recorded, provided the spacing between the trees did not exceed 10 yards. Last year the land was urban if there were more than two houses per 100 yards. This was altered to human dwelling and garden if fenced, if unfenced the urban area was taken as the dwelling and the bare earth around the house with up to 50% coverage by vegetation.

The symbols adopted were the same as last year and are as follows:-

Cultivated land.

- SE Estate cane sugar. This was mapped from the estate maps but any doubtful cases were recorded.
- SG Good farmer's cane. All good cane, not recorded on estate maps, but special note should be made of cane which appears to be estate cane.
- SB Bad farmer's cane. Cane grown by peasants in which less than 50% of the land is occupied by cane.
- R Rice. Any area showing evidence of a 1955 crop.
- F Short term food crops. Land occupied by tannia, eddoes, cassava, sweet potatoes, pidgeon peas, beans, tomatoes, maize and vegetables.
- CN Coconuts. Record only groups or parts of groups of six or more trees when the spacing does not exceed 10 yards.

O Orchard crops. Cashew nuts, tonka bean, pineapple.
Tree crops in stands of six or more with spacing not exceeding 10 yards. Pineapples only recorded in stands of 50 or more.

C Citrus. Record only groups or parts of groups of six or more trees when spacing does not exceed 10 yards.

Co Pure stands of cocoa or cocoa with bananas or coffee.

Coconuts, orchard crops, citrus and cocoa only recorded if they show evidence of being cared for e.g. cutlassed, clean drainage channels, etc.

Uncultivated land.

HB High bush - majority of vegetation over six feet high, includes hedges, bamboo, abandoned cocoa and timber.

LB Low bush - majority of vegetation under six feet, not suitable for grazing.

W Rivers, swamps and lakes. Swamps having 50% or more of swamp plants.

G Grazing - main stand of grass, not necessarily showing evidence of actual grazing.

NA Non-agricultural land used as roads, railways, factories, etc.

U Urban. Human dwelling and garden if fenced. If unfenced, dwelling and bare earth up to 50% coverage by vegetation.

VI.../

Not accounted for 5,017 acres

Total 26,243 acres

To make these figures applicable to the acreage which were in the survey area they were multiplied by $\frac{21,203}{26,243} = 0.81$

VI. ESTATE CANE STRATUM.

As stated in Chapter iv, it was decided to divide last year's cane arable stratum into estate cane stratum and arable stratum. The total acreage of the estate cane stratum was obtained from the estates who cropped land in the survey area. There were three estates concerned and one member of the team went to each. Furber went to Orange Grove and obtained a map of the estate which had a scale of 12 chains to the inch. The area of the estate which fell inside the survey area, i.e. all land south of the Churchill-Roosevelt Highway, was estimated from the map which was copied and reduced in scale to that of the ordnance survey map, i.e. 1.27 inches to one mile. The total acreage of Orange Grove Estate was 3,217 acres. 2,770 acres of this were in cane and 447 acres in factories, traces and railways.

Murfitt obtained maps from Caroni Limited, which were 0.63 inches to one mile. He took a copy of the estate map which was in the survey area making it the same scale as the ordnance survey map. The total acreage of Caroni Estate was 26,248 acres but only 21,263 acres fell in the survey area. He was given breakdown figures for the whole of the estate which were as follows:-

Cane	19,540 acres.
Rented to farmers	148 acres.
Pasture	580 acres.
Recreation grounds	136 acres.
Dwellings and Offices	350 acres.
House and garden lots	477 acres.
Not accounted for	<u>5,017 acres</u>
Total	<u>26,248 acres.</u>

To make these figures applicable to the acreage which were in the survey area they were multiplied by $\frac{21,263}{26,248} = 0.81$.

The /

The breakdown figures of the estate acreage which fell in the survey area were therefore as follows:-

Cane	15,828 acres.
Rented to farmers	120 acres.
Pasture	470 acres.
Recreation grounds	110 acres.
Dwellings and Offices	285 acres.
House and garden lots	386 acres.
Not accounted for	<u>4,064 acres.</u>
Total	<u>21,263 acres.</u>

The acreage which was not accounted for consisted of roads, traces, factories and swamp land. It is probable that it also included land which had been sold to householders. It was unfortunate that this figure was so large but in a further meeting the Manager was still unable to give a fuller account of this figure of 4,064 acres.

Buckler obtained maps from Woodford Lodge which were also twice the scale of the ordnance survey map. He reduced them to a scale of 1.27 inches to one mile when taking a copy. Woodford Lodge is split up as follows :-

Cultivated cane	5,135 acres.
Fallows, pastures, tracks	202 acres.
Housing, factories, roads	<u>202 acres.</u>
Total	<u>5,559 acres.</u>

Hence the total acreage of the three estates was 30,039 acres. The acreage of last year's cane arable stratum was 81,186 acres so this year's arable stratum is therefore 51,146 acres.

The .../

The acreages of the three strata are:-

Estate Cane	30,039 acres.
Arable	51,146 acres.
Bush	31,459 acres.
Total	<u>112,644 acres.</u>

VII. .../

VII. GENERAL TECHNIQUE OF SURVEYING.

The East-west grid lines were numbered from North to South. An approximately equal length of line was allocated to each member of the team. During the surveying of his lines, the person concerned acted as supervisor. This involved finding the quickest and most efficient way of surveying the lines. A preliminary survey of the line was carried out by the supervisor to see the type of vegetation and to find check points, which were put in at as frequent intervals as possible. Check points were used to ensure that the team walked on the correct line. The most reliable check points were mile-posts, road junctions and railways. Large bridges were used as check points but the smaller ones were not as reliable. When there was a small bridge marked on the map there were often two or three in quick succession on the road itself. The team were lucky in that the road had so many mile posts. All metal roads and many of the non-metal roads had mile posts at quarter mile intervals. The mile posts on the main roads were marked on the maps though in some cases their origin had been changed. The point from which the mile stones started had to be checked before they could be used. The large number of mile posts was a luxury which could not be expected in many colonies. Bends in the roads acted as check points on occasion as did distances from a road which would be running in the same direction as the line. The meanderings of rivers on the map were often very different in the field and therefore could not be used as check points. The boundary of the estate cane stratum was often a characteristic shape and this was used as a check point.

The supervisor was also responsible for choice of route and organisation of transport. The latter had to be arranged such that the minimum amount of time was spent in walking that was not on the line or on part of the line which had already been surveyed; this often proved difficult.

Ideally.../

Ideally, two men in the first team were dropped at A to survey to B. The second team drove from A to B and leaving the car on the check point proceeded to survey to C where they found the car parked on the check point by the first team who were surveying between C and D, and so on. Due to unequal distances between check points and the variable speed of surveying according to the vegetation this plan often had to be amended.

The lines were allocated as follows:-

Morgan	1, 3 and 4
Murfitt	6 and 7
Buckler	8 and 9
Furber	10, 11, 12 and 13.

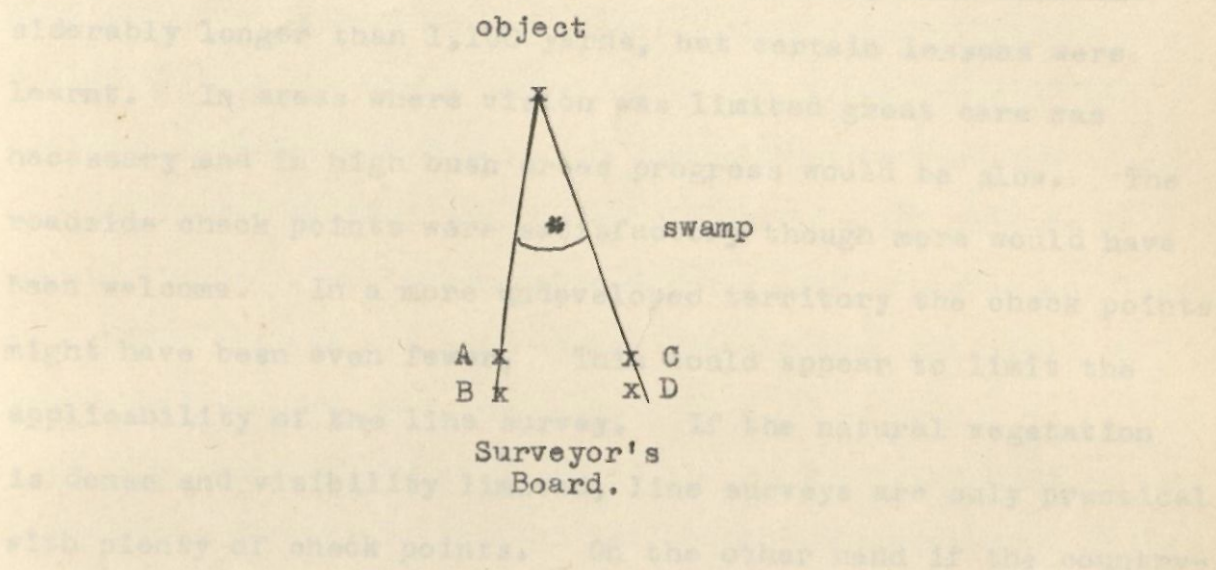
The whole of line 2 fell in the estate cane stratum, as did line 13. When the latter was surveyed it was found to be recently planted. Line 5 was surveyed as a team with no one acting as supervisor. This was done to appreciate the problems involved before the survey started. The team had walked in a straight line on the correct bearing for 1,100 yards but it was not known how they would fare with greater distances. Line 5 was chosen because it was the nearest line to the College which appeared to give a variety of field conditions. It took the team five half days to survey the whole of line 5, a distance of almost ten miles.

The team started at the Western end of line 5 on the afternoon of December 5th, 1955, and surveyed up to the Princess Margaret Highway where they finished very near to the check point. This was not surprising since the area was flat and the country open, allowing the team to walk to a landmark in the distance and so keep on the bearing. The magnetic deviation for 1955 was $8^{\circ} 30'$ West of North and increasing, so when going from West to East the team walked on a bearing of 99° and when walking East to West 279° . The.../

The only difficulty encountered on the first day was the crossing of some fairly wide streams in the rice fields.

The next afternoon the line passed through a land settlement area which had many roads. When the team eventually found the check point on the only road which was mapped they found that they were 7° off the line. Most of this work was done again the next afternoon and surveying taken up to the Southern Main Road. On this occasion the team ended at the check point on the railway line and the correct place on the Southern Main Road. The following afternoon the line was surveyed from the Southern Main Road to an area of high bush. Once again there were more roads than those shown on the map and the Cunupia river had changed course. This led to some wastage of time. This was the team's first encounter with high bush. Two members went in some distance but since there was no sign of any agriculture being carried out, it was decided to get this length of line by subtraction from the map. This was rather like the technique adopted by last year's team. When they surveyed an area of high bush they assumed it to be solidly high bush except for the areas they found by exploring all paths which led into the bush. The vegetation on this line was assumed to be bush unless a path could be found going into it. If a path was found, it was followed and its direction plotted so that the line could be surveyed by offsets from the path. Any crops other than high bush were paced and the distance residue between the check points was called high bush. Swamps could not be paced and these had to be found by subtraction from the map. When swamp and high bush occurred between the same check points, the one had to be paced. It had been hoped to develop a simple range finder so that the swamps could have been measured but this was unsuccessful. The .../

The proposed range finder consisted of a board and four pins, two of which were lined with the object i.e. A. and B.



C. and D. were then moved so that they formed a straight line with the object. In practice it was found that the board would have to be too big to be useful in the field. The angle * would be too small if a board of portable dimensions was used.

When swamps and high bush occurred between the same check points the high bush had to be surveyed. It was very slow and laborious but was possible. The first man walked into the bush making a track for the second and being kept on the bearing by the second man's instructions. When the first man was almost out of sight or wanted a rest, (usually the latter), the second man would pace up to the first. This method of surveying in bounds also had to be carried out when visibility was very limited and no land-marks could be seen. It was the only sure method of walking on the correct bearing.

For the final half day on line 5 the team split into pairs. One pair walked westwards from Madras Settlement Road to the high bush while the other pair walked eastwards to the Las Lomas Road, and finished on the check point. The remainder of the line presented few difficulties because of its proximity to the San Rafael Road, enabling check points to be made easily.

The..../

The work on line 5 has been outlined to illustrate the general problems of line surveying. The team finished the line convinced that they could walk accurately on a line considerably longer than 1,100 yards, but certain lessons were learnt. In areas where vision was limited great care was necessary and in high bush areas progress would be slow. The roadside check points were satisfactory though more would have been welcome. In a more undeveloped territory the check points might have been even fewer. This would appear to limit the applicability of the line survey. If the natural vegetation is dense and visibility limited, line surveys are only practical with plenty of check points. On the other hand if the countryside is undulating and open, long lines could be surveyed with few check points and the method would be rapid. Hunt (1952) considers that a map of at least one inch to one mile is required for line surveying and the team would readily agree with this.

From the experience of line 5, it was decided that it would be quicker to work in pairs and so ensure that the correct line was surveyed. The procedure described for high bush would probably have to be used for other types of vegetation where visibility is restricted. In open country progress would be faster and one man would record and the other would be responsible for direction. After pacing over rough country all day the size of the surveyor's yard is apt to be a little smaller than at the start of the day. This could probably be avoided by pacing in turn. This method would also help to ensure that mistakes were not made in the actual number of yards paced.

With the exception of the occasion noted, the team ended very near to the check point in each case but realised that this would not always happen, so certain rules were made. Distances could be measured from the map to an accuracy of ± 35 yards. It was therefore decided that the team had to finish their line within 70 yards of their check point or the line had to be resurveyed. On.../

On several occasions on line 5 the distance paced and the distance on the map did not coincide exactly and a ruling had to be made on this. The error in the map and taking distances from it would be much more constant than the team's pacing error. The pacing was therefore converted to the value shown on the map, the adjustment being made in proportion to the size of each crop. It was decided that this adjustment could only be made provided the discrepancy between map and team's pacing was less than 10%. If the discrepancy was greater than this then the line would have to be resurveyed.

The team decided to start at the South of the area so that if progress were slow the land near to the College could be done in term time. While travelling to the South each day, the team were able to become acquainted with the geography of the area. Roads or check points could be inspected going to or from work without special journeys being made. The problems of surveying the next first stage unit could then be appreciated before the team actually started to survey it.

All members of the team carried a note from the project Supervisor, Dr. A. L. Jolly, in case anyone objected to the team crossing their land. The note is in the appendix, but was never used despite the numerous notices "Trespassers will be prosecuted according to the law". Persons who were asked to establish the identity of sugar cane always gave an answer. It was often felt that the answer could be taken to mean estate or farmer's cane, so doubtful canes were recorded and their identity established by further visits to the sugar estate Managers.

Each team carried a compass and map. The position of the check points and the distance between them was marked on the map in Indian ink. The map was kept in a polythene bag as much as possible when in the field. Recording was done in a small pocket book. Each set of data would be prefaced by the line number, the starting check point, the direction the team were walking, the date and time. Each.../

Each crop was recorded as a symbol and a number of yards. A list of the symbols and their definition was also carried so that cases of unusual utilization could be classified. When the crop was greater than 100 yards each hundred was recorded to avoid mistakes being made. When not walking on the line a running total was kept of the distance to the actual line. A running total of the distance walked was kept sometimes to avoid a long addition at the next check point to see if the pacing was correct. The data was finished by writing in the position of the next check point and the distance away from this that the team had finished.

The details of the survey of each person's lines are found in the respective theses.

VIII. .../

The team then proceeded from Freeman road, bearing of 92° to Streatham Lodge road, a distance of 440 yards. The check point was 70 yards away from the centre of the Churchill-Roosevelt Highway. The next check point was 480 yards away on a track which was marked on the map a distance of 140 yards from the centre of the Churchill-Roosevelt Highway. The map showed two roads crossing the line between this check point and the river but they could not be identified on the ground, so the remainder of the line was done without a check point. The team ended 30 yards from the final check point which was 80 yards from the highway. This line presented few difficulties, the cane was in small places and the team paced straight through it. The remainder of the vegetation on the line could be walked through with ease.

(ii) Line three started at Pierce airport and finished at the O'Meara Savanne road, where the bush stratum commenced. There was also 360 yards immediately to the West of the Caroni river but this was found to be good farmer's cane. The Golden Grove Road was not as shown on the Ordnance survey map due to the construction of the airport. The.../

VIII. SURVEY OF LINES - ONE, THREE AND FOUR.

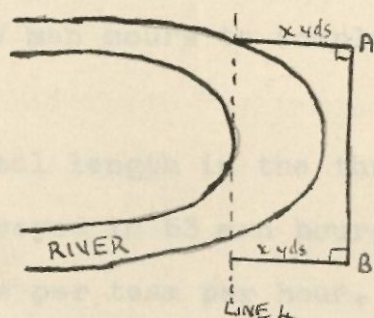
(i) Line one started at the Churchill-Roosevelt Highway and finished at the Tacarigua river where Orange Grove Estate started. The total length was 2,500 yards and was surveyed in two hours by a team of two. The team started from the western end. The line was found by pacing southwards along Freeman road 140 yards from its junction with another minor road. The remaining 76 yards to the West of this point were surveyed by walking on a bearing of 279° . The line met the Churchill-Roosevelt Highway at an acute angle. Half the width of the road was taken as being in the arable stratum as was half of the width of the Tacarigua river. The team then proceeded from Freeman road on a bearing of 99° to Streatham Lodge road, a distance of 440 yards. The check point was 70 yards away from the centre of the Churchill-Roosevelt Highway. The next check point was 480 yards away on a track which was marked on the map a distance of 140 yards from the centre of the Churchill-Roosevelt Highway. The map showed two roads crossing the line between this check point and the river but they could not be identified on the ground, so the remainder of the line was done without a check point. The team ended 20 yards from the final check point which was 60 yards from the highway. This line presented few difficulties, the cane was in small pieces and the team paced straight through it. The remainder of the vegetation on the line could be walked through with ease.

(ii) Line three started at Piarco airport and finished at the O'Meara Savanna road, where the bush stratum commenced. There was also 385 yards immediately to the West of the Caroni river but this was found to be good farmer's cane. The Golden Grove Road was not as shown on the ordnance survey map due to the construction of the Airport. The.../

The line started from a point which was 40 yards away from a right angled bend in the Orange Grove Road. The team could not pace across the Airport so the distance was obtained from the map. The first team walked on to the line from the point where the Piarco Savanna Road made a sharp turn South which was 220 yards away from a bridge marked on the map. They walked due North 800 yards and were on the line, this was checked by taking a back bearing on the hangars at the Airport which was 279° . The team then paced eastwards until they came to solid high bush. The second team walked westwards from the Mausica Savanna Road. The check point being one mile and 50 yards from the Churchill-Roosevelt Highway. They could find no crop apart from high bush and came back to fetch the first team who then walked eastwards from the Mausica Savanna Road while the other team walked westwards from the O'Meara Savanna Road. The latter found solid high bush but the former went in a thousand yards before the solid bush began which was devoid of paths. The large amount of bush on this line meant that many distances were obtained by subtracting the total of other crops from the distance between check points shown on the map. This assumed that the crops which were paced were measured accurately. At this stage however much surveying had been carried out and the pacing of the team had proved to be accurate. Twenty four man hours were spent on line three which was a distance of 7,593 yards.

(iii) Line four was started at the eastern end. The most easterly 2,030 yards were on the North bank of the Caroni River and the remainder on the South bank. The first team walked due South 280 yards from the ferry to get on to the line. They surveyed back to the Caroni River and then moved westward through the cocoa fields of the Centeno Experimental Station. The technique used for surveying in the cocoa was similar to that described for high bush in the last chapter. Progress.../

Progress was rapid and accurate. It was found that the bends in the Caroni River had become more accentuated than shown on the ordnance survey map and the line went through a bend in the river on two occasions. When this happened the team paced to the river bank then a fixed distance X at right angles and paced the distance AB in the cocoa.



This was equivalent to the amount of water which fell on the line. This procedure was adopted whenever an impassable feature of vegetation or topography occurred on the line. Having surveyed just over two thousand yards the river was encountered running in a northerly direction. This was the point to which the team were scheduled to survey. An unmapped bridge was further upstream so this was used to determine the width of the river, otherwise the team would have found the width by taking two bearings on a point on the opposite bank from two points a known distance apart on the near bank. The team then returned to the O'Meara ferry road to be picked up by the second team who had surveyed eastwards from the Caroni South bank road to the point where the first team had finished. The remainder of the line was completed by a team of three who started from the Princess Margaret Highway. The line was found by pacing 105 yards South of the bridge over the Madame Espagnole. The portion to the West of the Princess Margaret highway was under water so this distance was found by making it the hypotenuse of a right angled triangle formed by the 105 yards along the road to the bridge and 130 yards alongside the river which was on high ground. The team of two then proceeded eastwards to the check point on the next road which was 875 yards away and was found by the third team member in the car, and then on to Warren road where the cane stratum commenced. The .../

The team then moved to the point where the line cut the Caroni South Bank road and proceeded westwards. There were numerous roads and traces cutting the line which were not on the map but whose position could be fixed from the mile posts which were as marked on the map. The third member of the team therefore found the check points while the other two surveyed the line. Line four took 27 man hours to complete and was a distance of 12,352 yards.

The total length in the three lines was 22,445 yards and this was surveyed in 53 man hours, i.e. 423 yards per man hour or 846 yards per team per hour. This does not include time taken travelling to and from the lines but includes time taken for any travelling between check points on the lines themselves. The remainder of the lines took 257 man hours to complete. The team therefore took 310 man hours to survey 106,930 yards. This is an average of 690 yards per team per hour.

IX. .../

Error variance per unit = $\frac{1}{n} \sum d^2$

where n = the number of differences = 100

Sampling error = $\sqrt{\frac{1}{n} \sum d^2}$

where n = the number of units = 100

The calculation of the sampling error of good farmer's cane is as follows:-

Total length 30 = 1000

$\sum d^2 = 7,123,045$

$\frac{1}{n} \sum d^2 = 71,230.45$

S.E. = $\sqrt{71,230.45} = 266.89$ yards

IX. ANALYSIS OF RESULTS.

(1) USING TWO STAGE SAMPLING.

As explained in Chapter iv. Section (iv), the field data was put together in the form of a continuous line to avoid wastage. The western end of line three followed the east of line one because it was the nearest point. The eastern end of line three was joined to the eastern end of line four and the western end of line four was joined to the west of line five and so on. This continuous line was then split into 106 lines of 1,000 yards each. Each member of the team was responsible for the calculation of sampling errors of certain crops. This author was responsible for the calculations of the sampling errors for rice, grazing and good farmer's cane.

As explained in Chapter iv, Section (vi), there is no fully valid estimate of the sampling error of a systematic sample. The error variance is estimated from the differences between the members of the pairs of successive units.

$$\text{Error variance per unit} = S^2 = \frac{1}{2} \frac{S(dy^2)}{n-1}$$

Where $n-1$ = the number of differences = 105.

$$\text{Sampling error} = \sqrt{n \times S^2}$$

where n = the number of units = 106.

The calculation of the sampling error of good farmer's cane is as follows:-

$$\text{Total length SG} = S(y) = 18250.$$

$$S(dy^2) = 7,223,058.$$

$$S^2 = \frac{7223058}{2 \times 105} = 34395$$

$$S.E. = \sqrt{106 \times S^2} = \pm 1909.43 \text{ yards.}$$

Total.../

Total length of lines = 106,000 yards = 51,146 acres = acreage of arable stratum.

Then 1 yard = 0.482 acres.

$$\begin{aligned} \text{Sampling Error} &= \pm 1909.43 \times 0.482 \text{ acres.} \\ &= \pm 920.0 \text{ acres.} \end{aligned}$$

$$\begin{aligned} \text{Total acreage of S G} &= 18,205 \times 0.482 \text{ acres.} \\ &= 8774.8 \text{ acres.} \end{aligned}$$

$$\begin{aligned} \% \text{ S E} &= \frac{920 \times 100}{8774.8} \\ &= \underline{\underline{10.49\%}} \end{aligned}$$

Similar calculations were carried out for rice and grazing.

RICE

$$\begin{aligned} \text{Total acreage of rice} &= 6,605.96 \text{ acres.} \\ \text{Standard Error} &= \pm 729.58 \text{ acres.} \\ \% \text{ Standard Error} &= 12.00 \%. \end{aligned}$$

GRAZING.

$$\begin{aligned} \text{Total acreage of grazing} &= 9,148.2 \text{ acres.} \\ \text{Standard Error} &= \pm 236.0 \text{ acres.} \\ \% \text{ Standard Error} &= 2.58\% \end{aligned}$$

As an interesting comparison the standard error of good farmer's cane and grazing were obtained by another method. The units were not allocated at random within the strata but for this calculation it was assumed that the units were selected at random within the arable stratum.

Sum of squares of deviation from the mean =

$$S(y^2) = \frac{(Sy)^2}{n}$$

Variance = $\frac{\text{Sum of Squares of deviations from mean}}{n - 1}$

$$\text{Standard Error} = \sqrt{\frac{\text{Variance}}{n - 1}}$$

For SG.... /

For S G. Variance = 63,352.32
 S.E. = ± 251.70 yards.
 = $\pm 251.70 \times 0.482$ acres.
 = ± 121.32 acres.

$$\% \text{ Standard Error} = \frac{121.32 \times 100}{8774.8} = 1.38\%$$

For G % S.E. = 1.34%

This method was not applied to rice because the findings of Murfitt attracted the attention of the team. From the pilot survey outlined in Chapter iv. Section (ii) there was little to choose between 550 yards or 1,100 yards in a line but the team felt that there was a particular length of line which would give a minimum value to the sampling error. Obviously the team wanted to find this length, so Murfitt undertook an investigation into the optimum length of line. He took six lines of 1,000 yards at random and found the percentage sampling error for all the crops, then split these lines into 12 lines of 500 yards, 24 lines of 250 yards and 60 of 100 yards. Instead of finding an optimum length of line he found that the sampling error became progressively smaller as the lines were reduced in size. This meant that there was a positive correlation between lines, i.e. the content of the first line governed what was in the next line and so on. It was then thought that a longer second stage unit should be used to avoid this positive correlation. When sampling is 100% at the second stage it is impossible to find a length of second stage unit which does not give positive correlation. Second stage sampling therefore had to be abandoned and the eleven grid lines were treated as the first stage and only set of samples.

(ii) /

(11) RECALCULATION OF LAST YEAR'S RESULTS.

One hundred percent sampling at the second stage was used last year and gave a reduction in sampling error. This led the team to look into last year's method of calculation of sampling error. This reduction in error may have been due to an incorrect method of calculation or positive correlation between the second stage units. The latter was supposedly avoided last year by dividing the first stage units into sixteen sub-units in a completely random manner.

Last year's team calculated the sampling error for a stratified random sample with possibly unequal variances within strata. This method was correct when finding the sampling error of the first stage units because they were drawn at random from within the strata but could not be used when two stage sampling was used. Last year's calculation assumed that all the sub-units were drawn at random from within the stratum when in fact only the first stage units were drawn at random.

If the sampling fraction at the first stage is small, the total sampling error of multistage sampling is obtained from the first stage unit values, estimating each unit value from the results of the sampling at the second and following stages, and using the method of estimation appropriate to the method of sampling at the first stage. The additional variability contributed by the second and following stages is automatically included in this estimate of error (Yates 1953 B).

If the first stage sampling fraction is not small, the calculation is as follows:-

If n' is the number of first stage units selected and n'' second stage units selected from the first stage units and S'^2 the estimate of the sampling variance of the first stage unit means while S''^2 is the variance of the second stage units about the first stage unit means f' and f'' are the first and second stage sampling fractions respectively.

Let.../

Let the sampling variance of the mean of the population = $V(\bar{y})$

$$\text{Then } V(\bar{y}) = \frac{1 - f'}{n'} s'^2 + \frac{f'(1 - f'')}{n' n''} s''^2$$

But in this case the second stage sampling fraction is unity so $(1 - f'')$ is zero so the second term of the expression becomes zero.

$$\therefore V(\bar{y}) = \frac{1 - f'}{n'} s'^2$$

This does not use the second stage units at all so there was little point in carrying out a two stage sample. As pointed out by Jolly (1954) "the advantage of multistage sampling is not that it provides a more accurate or even as accurate results but that it reduces the labour of dealing with a large number of small units scattered over an area". Second stage sampling was carried out last year to improve the accuracy and not for the latter reason which does not apply because the first stage units were 100% sampled. Jolly (1954) also points out that it is dangerous to take a large number of second stage units from first stage units because the second stage units can become positively correlated. The team therefore calculated the sampling errors of the cane arable stratum using six units only. This was done so that a fair basis of comparison could be made between this year's results and last year's. The sampling errors of the bush stratum were also recalculated because these were needed to combine with this year's results to give estimated acreages and sampling errors for the whole survey area.

The method of calculation used was as shown by Humphries (1955 B) in the method which he calls method two.

The.../

The results were as follows:-

Cane Arable stratum only.

CROP	Sampling Errors as Percentage	
	96 Units Last year's Method	6 Units Corrected method
SG	70.8	64.67
SB	36.2	47.59
R	37.4	54.44
F	20.7	35.97
O	36.8	67.45
C	38.8	73.15
Co	88.8	95.30
HB	22.2	80.72
LB	24.5	74.19
W	67.8	54.92
G	17.1	15.27
NA	16.6	17.42
U	20.6	36.41

(iii) CALCULATION OF SAMPLING ERROR USING GRID LINES AS SAMPLING UNITS.

The grid lines varied in length from 2,500 to 17,164 yards. This meant that an adjustment had to be made for this when calculating the sampling error using the grid lines as the sample units. The method of calculation used earlier for the 1,000 yard length lines is only applicable when the lines are of approximately equal length.

If Y = length of crop in a grid line.

X = length of grid line.

dy.... /

dy = Successive differences in length of crop between pairs of grid lines,

dx = Successive differences in length of grid line.

r = $\frac{\text{Total length of crop}}{\text{Total length of line surveyed.}}$

$$\text{Then } Q = \frac{1}{2} S(dy^2) - 2r \frac{1}{2} (dx \times dy) + r^2 \frac{1}{2} S(dx^2)$$

Good farmer's Cane.

dx	dy	dx.dy
5093.	- 534	- 2719662
1533	3277	5023641
8038	-1536	- 12346368
- 2830	- 100	283000
- 1215	-1419	1724085
- 4403	583	- 2575755
2148	1680	3608640
- 780	-1660	1294800
- 1448	410	- 593680
- 3842	70	- 268940

$$\frac{1}{2} S(dx^2) = 71,924,844$$

$$\frac{1}{2} S(dy^2) = 10,749,983$$

$$S(dx dy) = -6570239.$$

$$r = \frac{18205}{106930} = 0.17025$$

$$r^2 = 0.029.$$

$$Q = \frac{1}{2} S(dy^2) - 2r \frac{1}{2} (dx, dy) + r^2 \frac{1}{2} S(dx^2)$$

Q...2

$$Q = 13,954,386.$$

$$Sq^2 = \frac{Q}{10} = 1395438.6$$

$$\text{Sampling Error} = \sqrt{Sq^2 \times 11} = \pm 3917.88 \text{ yards.}$$

$$\% \text{ Sampling Error} = \frac{3917.88}{18205} \times 100 = 21.52\%.$$

Length of lines surveyed = 106,930 yards = 51,146 acres =
acreage of arable stratum.

Then 1 yard = 0.4783 acres.

Estimated acreage of Good Farmer 's Cane in arable stratum.

$$= 18205 \times 0.4785.$$

$$= 8707.5 \text{ acres.}$$

$$\text{Sampling Error} = 21.52\%.$$

The sampling errors and estimated acreages were calculated for rice and grazing in a similar way. The results are as follows:-

Estimated acreage of grazing in arable stratum = 9,164.2 acres.

$$\text{Sampling Error} = 18.86\%$$

Estimated acreage of rice in arable stratum = 6,610.1 acres.

$$\text{Sampling Error} = 23.85\%.$$

The crops were grouped into three types, namely agricultural cultivated, agricultural uncultivated and other uses. Agricultural cultivated included citrus, coconuts, cocoa, orchard crops, rice, food crops, bad and good farmer's Cane. High bush, low bush and grazing were in the agricultural uncultivated group while non-agricultural, urban and water were called other uses.

The.... /

The author was responsible for calculating the estimated agricultural cultivated acreage and its sampling error.

In this case Y = length of agricultural cultivated land on grid line.

X = length of grid line.

Y	dx	dy	$\Sigma dx.dy$
11919	-	-	-
552	5093	- 1367	- 6962131
6962	1533	6410	9826530
8207	8038	1245	10007310
6563	- 2830	- 1644	4652520
3694	- 1215	- 2869	3485835
1400	- 4403	- 2234	9836302
4268	2148	2808	6031584
3114	- 780	- 1154	900120
3873	- 1448	759	- 1099032
3054	- 3842	- 819	3146598

Agricultural Cultivated.

$$\frac{1}{2} S(dx^2) = 71,924,844.$$

$$\frac{1}{2} S(dy^2) = 35,447,444.$$

$$S dx.dy. = 39,825,636.$$

$$r = \frac{43666}{106930} = 0.4084$$

$$r^2 = 0.1668$$

$$Q = 31,179,718.$$

$$Sq^2 = 3,117,971.8.$$

Sampling..../

$$\text{Sampling Error} = \sqrt{34297689.8} = \pm 5856.42 \text{ yards.}$$

$$\% \text{ Sampling Error} = \frac{5856.42}{43666} \times 100 = 13.41\%$$

$$\begin{aligned} \text{Acreage in Arable Stratum} &= 43666 \times 0.4785 \\ &= 20.890 \text{ acres.} \end{aligned}$$

Agricultural Uncultivated.

$$\text{Acreage in arable stratum} = .26670 \text{ acres.}$$

$$\text{Sampling Error} = 11.72\%$$

Other Uses.

$$\text{Acreage in arable stratum} = 3604 \text{ acres.}$$

$$\text{Sampling Error} = 18.07\%.$$

The number of yards of good farmer's cane on a grid line will be correlated more with the length of cultivated land on that grid line than with the total length of the grid line. Similarly the length of high bush on a line is correlated more with the length of uncultivated land on that grid line than with the total length of grid line. The sampling errors of the crops were therefore calculated using the total length of cultivated land on a grid line as the supplementary variate for citrus, coconuts, cocoa, orchard crops, rice, food crops, good and bad farmer's cane. The total length of uncultivated land on a grid line acted as supplementary variate for high bush, low bush and grazing, while the total length of other uses on a line was supplementary variate for non agricultural, urban and water.

Y = length of crop on grid line.

X = length of agricultural cultivated land on grid line.

dy = Successive differences in length of crop between pairs of grid lines.

dx = Successive differences in lengths of agricultural.../

agricultural cultivated land between pairs of grid lines.

Good Farmer's Cane.

dx.	dy.	dx.dy
-	-	-
-1367	- 534	729978
6410	3277	21005570
1245	-1536	- 1912320
-1644	- 100	164400
-2869	-1419	40711
-2234	585	- 1306890
2808	1680	4717440
-1154	1660	- 1915640
759	410	311190
- 819	70	- 57330

$$\frac{1}{2} S(dx^2) = 35,447,444.$$

$$\frac{1}{2} S(dy^2) = 10,749,983.$$

$$S(dxdy) = 25,807,509.$$

$$r = \frac{18205}{43666} = 0.4169$$

$$r^2 = 0.1738$$

$$Q = 6,151,599$$

$$Sq^2 = 615,159.9$$

$$\text{Sampling Error} = \sqrt{6766758.9}$$

$$= 2601.30$$

$$\% \text{ Sampling Error} = \frac{2601.30}{18205} \times 100 = 14.28\%$$

The.../

The sampling errors of rice and grazing were also reduced compared to the results obtained when using total length of grid line as supplementary variate.

Good farmer's Cane	14.28%
Rice	20.76%
Grazing	13.58%

Arable Stratum.

Crop	Estimated Acreage.	Sampling Errors %			
		Difference method,	Sum squares method	length of Grid line as x.	Length of Group as x.
C	1102.0	29.49	3.48	50.33	40.77
CN	752.8	-	5.52	78.54	80.73
HB	14,438.4	6.24	1.26	11.53	8.17
F	2,093.0	-	-	19.46	14.93
Co	1,177.6	13.11	3.75	21.55	59.00
G	9,164.2	2.58	1.34	18.86	13.58
R	6,610.1	11.99	-	23.85	20.76
SG	8,707.5	10.49	1.38	21.52	14.28
LB	3,053.5	14.96	2.20	29.81	30.48
NA	503.7	3.87	3.68	30.62	72.00
O	104.7	66.82	24.44	61.11	63.08
SB	337.7	26.95	3.03	32.25	39.12
U	1202.5	24.69	21.15	26.78	34.38
W	1897.9	22.78	2.95	39.39	33.40

(iv)

(iv) COMPARISON OF THIS YEAR WITH LAST YEAR.

CROP	THIS YEAR	LAST YEAR
C	40.77	73.15
CN	80.73	100.0
HB	8.17	80.72
F	14.93	35.97
Co	59.00	95.30
G	13.58	15.27
R	20.76	54.44
SG	14.28	64.67
LB	30.48	74.19
NA	72.00	17.42
O	63.08	67.45
SB	39.12	47.59
U	34.38	36.41
W	33.40	54.92

This table shows that the team reduced the sampling errors of last year's cane arable stratum which was the object of the survey. The reduction was not as large as the team had originally hoped, though the errors from two stage sampling were lower than those forecast by the pilot survey. The area is extremely variable and any great reduction in sampling area will only be brought about by more intensive sampling or a less detailed crop classification. The latter was tried this year when the crops were split into agricultural cultivated, agricultural uncultivated and other uses but the sampling errors remained between 10 and 20 percent; the actual values being 13%, 11% and 18% respectively.

(v).... /

(v) Combination of this year's results with last year's bush stratum.

The variances of the bush stratum had to be re-calculated for four units instead of the 64 which were used last year. The variances of the crops of this year's arable stratum were converted to acres and added to those of the bush. The square root of the total gave the sampling error for the whole area.

RICE

	n_i	$n_i - 1$	$S(y - \bar{y})^2$	$V(y_i)$
Bush	4	3	269.53	4,578.25
Arable				<u>3,950,295.89</u>
				<u><u>3,954,874.14</u></u>

$$V(y_i) = \frac{S(y - \bar{y})^2}{n_i - 1} = n_i (1 - f_i) g^2$$

f_i = Sampling fraction g = raising factor.

$$\begin{aligned} \text{Sampling Error} &= \sqrt{3,954,874.14} \\ &= \pm 1,988.69 \text{ acres.} \end{aligned}$$

$$\text{Acreage of rice in bush} = 134.17 \text{ acres.}$$

$$\begin{aligned} \text{Acreage of rice in arable (} \\ \text{stratum)} &= \underline{6,610.11 \text{ acres.}} \\ &= \underline{6,744.28 \text{ acres.}} \end{aligned}$$

$$\begin{aligned} \% \text{ Sampling Error} &= \frac{1988.69 \times 100.}{6744.28} \\ &= 29.49\% \end{aligned}$$

The calculation was carried out in similar manner for grazing and good farmer's cane.

$$\begin{aligned} \text{Total acreage of grazing} &= 2,002.26 + 9,164.23 \\ &= 11,166.49 \text{ acres.} \end{aligned}$$

Sampling /

Sampling Error = 20.36%

Total acreage of SG = 764.39 + 8,707.45

= 9,471.84 acres.

Sampling Error = 19.41%.

CROP	Acreage in BUSH	Acreage in Arable Stratum.	Total Acreage	S.E.
C	297.5	1,102.0	1,399.5	47.07
CN	-	752.8	752.8	80.7
O	85.3	104.8	190.1	62.96
F	1,011.0	2,093.0	3,214.0	18.44
G	2,002.3	9,164.2	11,166.5	20.4
R	134.2	6,610.1	6,744.3	29.5
SB	567.4	337.7	905.1	39.54
SG	764.4	8,707.4	9,471.8	19.4
HB	21,326.6	14,338.4	35,665.0	20.39
LB	827.6	3,053.5	3,881.0	35.79
NA	132.6	503.6	640.2	82.10
U	289.3	1,201.5	1,490.8	40.21
W	77.5	1,897.9	1,975.4	46.53
Co	2,783.5	1,177.5	3,961.0	45.80

X. .../

X. CONCLUSIONS.

- 1). The map was a satisfactory frame.
- 2). The classification was workable.
- 3). Increased stratification improved the sampling errors.
- 4). Line surveying worked satisfactorily. The teams averaged 823 yards per hour.
- 5). The method of calculation which gave the lowest sampling errors was when the length of crop in a unit was adjusted by covariance according to the length of cultivated, uncultivated or other uses in that unit.
- 6). Line sampling reduced the arable stratum sampling error. The team therefore achieved their object.
- 7). The sampling errors are still too high for all but the most general purposes. Last year's and this year's surveys can be used as pilot surveys for future work.
- 8). The team gained very useful practical experience of surveying in the field and learned much about the theories of sample surveys. This will be very useful if members of the team are ever called upon to organize or take part in future surveys.
- 9). The field surveying would have been much easier in the dry season when walking conditions would have been easier and the cane harvested, giving a much wider field of vision.
- 10). Much more time was spent in the calculation of results than in the field survey.
- 11). The acreage of arable stratum was 51,146 acres. 40.8% of this was cultivated. Sampling Error 13%. 52.1% of this was uncultivated. Sampling Error 11%. 7% of this was other uses. Sampling Error 18%.

XI. RECOMMENDATIONS.

If a similar survey were carried out again the author recommends that:-

- 1). The Western boundary of the bush stratum be moved westwards.
- 2). Possibility of further stratification should be investigated by examining the contents of this year's sample units.
- 3). If lines of 1,100 yards were laid down over the area systematically, a large number would be the same as this year, so many more lines could be surveyed.
- 4). Line surveying in the bush is no use unless labour is employed to cut a trace.
- 5). If surveying is done by mapping, sampling should be multi stage. More first stage units will have to be found than were mapped in 1954/55 survey and the first stage sampling fraction increased and second stage decreased.
- 6). Multi phase sampling could be used to give more information with little more expenditure of time and money.

XII. .../

XII. SUMMARY.

A land utilization survey was carried out on the Northern plain of Trinidad by sampling methods. A map with scale 1:50,000 was used as a frame. The area was stratified into cane, bush and arable strata. The cane stratum was obtained from sugar estate maps. The bush stratum was sample surveyed last year. The arable stratum was surveyed by lines laid down systematically from West to East across the area. It was initially intended to be a two stage sample but this was statistically unsound. There were eleven lines of varying lengths. They were adjusted to the same length by covariance. Four methods of calculation of sampling error were used though two of these were statistically unsound. The results were better than last year but the sampling errors were still too high for most purposes. The results of arable stratum were combined with last year's bush. Recommendations were made.

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2nd Edition. Charles Griffin & Co., Ltd., London. p.9.

Yates, F. (1953B).

ibid. p.227.

Thirteen lines 1,100 yards each on pilot lines as follows:
Unit 49.

ACKNOWLEDGEMENTS.

The writer wishes to record his thanks for assistance and advice given by his supervisor, Dr. A. L. Jolly, also to the estate managers for their help in compilation of the data of the estate cane stratum.

Unit 50.

	Line one	Two	Three	Four	Five	Six
NA	0	0	0	0	0	0
U	0	0	0	0	0	0
SS	345	0	0	0	0	0
HB	418	701	674	1037	222	1037
LB	286	198	0	0	0	0
R	0	0	330	0	0	0
O	0	110	0	0	0	0
ST	0	0	0	0	0	0
P	0	0	0	0	0	0

Unit 51.

	Line one	Two	Three	Four	Five
U	0	0	0	0	0
NA	0	0	0	0	0
T	0	0	0	0	0
HB	1030	0	0	0	0
U	0	0	0	0	0
R	0	0	0	0	0
P	0	0	0	0	0
SS	0	0	0	0	0
HB	0	0	0	0	0

Calculated....

APPENDIX A.

Thirteen lines 1,100 yards each on pilot lines as follows:-

Unit 49.

	Line one	Line Two	Line Three
NA	4	22	4
U	84	-	-
SB	176	-	-
F	88	-	-
SG	88	496	-
HB	264	-	646
G	36	-	-
SE	360	-	230
LB	-	22	-
C	-	560	220

Unit 52.

	Line one	Two	Three	Four	Five	Six.
NA	3	3	3	3	3	3
W	8	-	-	-	-	-
56	385	-	88	-	-	-
HB	418	701	674	1097	572	1097
LB	286	198	-	-	440	-
R	-	-	330	-	-	-
O	-	110	-	-	-	-
SE	-	88	-	-	-	-
F	-	-	-	-	-	-

Unit 71.

	Line one	Two	Three	Four
G	56	106	8	52
NA	4	21	11	5
W	10	-	50	-
SE	1030	671	651	570
U	-	242	66	95
R	-	-	66	378
F	-	60	110	-
SB	-	-	44	-
HB	-	-	88	-

Calculation.... /

Calculation of Sampling Error for S.G. from pilot lines.

	d.	
385	-	
-	385	
88	88	Sum of squares of successive differences =
-	88	$S(dy^2) = 584,032.$
-	-	
-	-	Error variance = $S^2 = \frac{1}{2} \frac{S(dy^2)}{n^1}$
88	88	
496	408	When n^1 = number of differences,
-	496	$S^2 = \frac{584,032}{24} = 24,335.$
-	-	
-	-	For 100 lines $S^2 = 243.35$
-	-	
-	-	. . . S.E. = ± 15.60 yards.
-	-	
Total	<u>1057</u>	New length S.G. per line = $\frac{1057}{13} = 81.3$ yards
		. . . % S.E. = $\frac{1560}{81.3} = 19.2\%.$

(Signed) A. L. Jolly.

FIELD RESULTS.

Line (1) West to APPENDIX B. Line (3) West to East.

18W4 (Churchill Roosevelt) 2653M

COPY

42A (Freeman Road) Imperial College of Tropical Agriculture,
Trinidad, B. W. I.

82F 3,6240 (Barrackman)

73 1,3908M

To whom it may concern.

402 3032

The bearer, Mr. H. E. G. Morgan, is a post graduate student of the Imperial College of Tropical Agriculture who is engaged in a sample survey of land use in this area. Being a trained Agriculturist, he will not damage any crops he may find necessary to inspect, loose animals, or cause fire, etc.

123 The information he is collecting is simply the use to which land is at present being put, and is not at all concerned with taxation, police or other government activities.

92A (check As his Supervisor, I should be grateful if you would allow him access to your land.

65 6230 2032

21A (Signed) A. L. Jolly. 26

43 12030 212

53 1772

433 2330 207

250 1,442M

205 26020 20

2708 5W (Teechigwa) 92A (S'Kakra)

73 (check point). (Perry Road)

727

1532

505

2024

APPENDIX C.

FIELD RESULTS.

Line (1) West to East.	Line (1) Cont.,	Line (3) West to East.
16NA (Churchill Roosevelt)	2W	385SG
60G	228F	5G
4NA (Freeman Road)	5G	6NA (Orange (Grove Road)
20G	2LB	5G
9F	5G	3,624G (Aerodrome)
7G	124SG	1,090HB
84F	25SB	5G
46G	80SG	4NA (Mausica (Savannah Rd)
28U	6G	5G
8G	59SG	565HB
3NA	22G	SW
2G	66SG	130HB
25U	3NA	25F
16F	27G	7HB
15HB	20LB	3W
50CN	16F	5HB
9NA (check point)	28G	64Co
35U	7LB	70SG
5G	62SG	20HB
3NA	19G	8W
4G	120SG	48Co
60F	5G	17HB
42G	93SG	40F
25U	6G	1,449HB
30F	252SG	4G
27OR	5W (Tacarigua) (River)	2NA (O'Meara (Ferry Road)
7G (check point).		
72F		
15OR		
50G		
48SG		

Line (4) West to East	(cont.)	(cont.)
SW	4G	225SG
10LB	10R	5G
25G	4G	35R
167R	10R	25F
2W	4G	37SG
12G	10R	20F
12NA (P.M. Highway)	170SG	77SG
6G	3G	3G
2W	125R	53SG
22G	280G	66SG
8W	19SG	35F
141R	15F	14SG
14W	35SG	66SG
561R	42G	8G
3G	45U	130SG
3NA (Check point)	3G	2W
4G	2NA (Warren Road)	30G
2W	37SG	3W
455R	5G	8SG
4NA	62R	7G
473R	4G	112G
4G	133R	510SG
3NA	5G	8G
4G	160R	280SG
330R	82SG	8G
4W	18G	340SG
131R	164SG	40G
2G	7G	4NA
3NA	130SG	104G
2G	2R	8LB
2W	7G	15SG

Line (4) continued.	(cont.)	(Cont.)
25F	214SG	7G
20G	33F	221R
20F	27SG	2G
30LB	62F	1W
16F	180SG	3G
35G	3G	211R
20F	35F	6G
33LB	230C	29LB
2G	101F	30HB
5NA	44LB	60W
27U	70W	35HB
39CN	35HB	235Co
44C	70W	2G
5G	33HB	4NA
20F	2G	2G
14U	4NA	111Co
27G	2G	140W
33U	49SG	55Co
6G	6G	9G
6NA (Caroni Road)	128SG	57Co
40G	2G	60W
19U	6NA	55HB
28G	2G	60W
22U	200SG	30HB
6G	161G	167Co
25F	13SG	4G
30SG	54F	64Co
39LB	8G	140W
100G	2W	37Co
20SG	8G	5G
18F	125R	135Co
		104HB
		21G
		973Co
		12HB
		248Co
		44F
		(Caroni River).

APPENDIX D.

Line No.	Length of SG.	Differences	Line No.	Length of SG.	Differences	Line No.	Length of SG.	Differences.
1	0	-	34	0	0	68	0	0
2	439	+439	35	0	0	69	0	0
3	775	+336	36	0	0	70	0	0
4	0	-775	37	0	0	71	399	+399
5	0	0	38	0	0	72	713	+314
6	0	0	39	0	0	73	224	-489
7	0	0	40	0	0	74	250	+ 26
8	0	0	41	0	0	75	625	+375
9	70	+ 70	42	83	+ 83	76	254	-371
10	0	- 70	43	0	- 83	77	0	-254
11	0	0	44	91	+ 91	78	0	0
12	0	0	45	134	+ 43	79	0	0
13	0	0	46	54	- 80	80	21	+ 21
14	746	+746	47	431	+377	81	217	+196
15	329	-417	48	383	- 48	82	568	+351
16	291	- 38	49	541	+158	83	23	-545
17	754	+463	50	299	-242	84	187	+164
18	800	+ 46	51	0	-299	85	219	+ 32
19	695	-105	52	18	+ 18	86	0	-219
20	37	-658	53	61	+ 43	87	60	+ 60
21	0	- 37	54	118	+ 47	88	49	- 11
22	0	0	55	63	- 55	89	0	- 49
23	206	+206	56	29	- 34	90	17	+ 17
24	782	+576	57	150	+121	91	366	+349
25	33	-749	58	0	-150	92	34	-332
26	77	+ 44	59	0	0	93	211	+177
27	0	- 77	60	0	0	94	166	- 45
28	696	+686	61	0	0	95	542	+376
29	322	-374	62	0	0	96	221	-321
30	0	-322	63	0	0	97	98	-123
31	0	0	64	158	+158	98	0	- 98
32	0	0	65	0	-158	99	214	+214
33	0	0	66	0	0	100	124	- 90
			67	0	0	101	0	-124
						102	172	+172
						103	134	- 38
104	484	+360	105	826	+432	106	244	-682

1st copy

APPENDIX E.

MAP OF TRINIDAD

SHOWING SURVEY AREA

KEY:-

— = ROADS

++++ = GOVT. RAILWAY

