design for later surveys. Sometimes such preliminary surveys have to be carried out more than once, and the scale of operations is gradually increased until finally the whole area or universe is fully covered. For example, in the Bengal crop survey a pilot survey was first carried out in 1937 covering only 124 square miles at a total cost of about £1,100. In 1938, a second survey was organized, in the light of the experience gained in the previous season, on a larger scale covering about 400 square miles at a cost of £2,500; next year the total area covered was nearly 2,600 square miles at a cost of £6,000. In 1940 the area covered was nearly 20,600 square miles at a cost of £8,100; and finally, in 1941 the whole jute tract of Bengal, measuring about 60,000 square miles, was surveyed at a cost of £10,100.

In the exploratory stage the object is to gather as quickly as possible some rough idea of the variance function, cost of operations, type and nature of human agency likely to be suitable for the field work or fluctuations from one region to another (*i.e.*, the distribution over space) of the elements or statistical variates proposed to be estimated in the survey. An intensive study is often essential in the exploratory stage. The cost per square mile (or per unit) is therefore necessarily high, but as basic information begins to be gathered the design of the survey steadily improves, and the cost per unit rapidly decreases in subsequent surveys.

In the Bihar crop survey the exploratory work was done in only two districts covering about 8,000 square miles from February to April 1944. As conditions were found in many ways similar to those in Bengal, it was possible to organize a full-scale provincial crop survey in Bihar covering about 70,000 square miles in the next crop season extending from July to September 1944. This survey was, however, admittedly weak in certain respects. In the next survey in the main winter rice season from October to December 1944 the Bihar crop survey was, however, fully organized. This shows that where previous experience is available, it is possible to expedite the exploratory phase.

In extensive surveys it is usually necessary to employ a large number of staff in both field and statistical branches. For example, in the Bengal crop survey the field staff consists of about 350 workers, who actually go round from village to village, with a number of inspectors and supervisors at the top. The total statistical staff in the Institute for computational and technical work consists at present of about 375 workers inclusive of all grades in 1945–46. Giving necessary training to the staff is an important part of the work, and takes a good deal of time. The exploratory approach is often convenient from this point of view.

In socio-economic or demographic enquiries also it has been found extremely helpful to conduct a small-scale preliminary enquiry, and then make final arrangements in the light of the experience gained thereby. A pilot survey enables forms and schedules, staff organization and other details being thoroughly worked out in advance, and often saves its cost many times over.

In large-scale surveys which are repeated from season to season or from year to year the exploratory development of technique, of course, continues all the time. As pointed out by A. Wald, the underlying logic is the same as in sequential tests. Advantage is taken of all available information in preparing the design of the survey. As information accumulates, the efficiency of the survey continues to improve from one survey to another.

Multiple surveys. A special form of the exploratory approach also deserves mention. Consider an actual example. In 1941 it was desired to develop a method for forecasting the yield of cinchona bark in blocks of standing plants each covering from 20 to 40 acres. In the first survey a number of physical measurements, such as girth, height, number of shoots, surface area of the plant, etc., were made on a number of standing plants picked up at random. These plants were then uprooted and the yield of bark was determined for each plant separately. Coefficients of correlation were then determined between the yield of bark and the different physical measurements. Three measurements—namely, height of the plant, girth at a height of 6 inches above ground, and the number of shoots—were selected for final use. A number of plants in the particular block under survey can be then picked up at random and these three physical characters measured for each plant, from which the average values of these three characters for the block as a whole can be determined. The plants are not, however, uprooted, and no direct measurements of bark yield are made during the second survey. (The number of plants in the block can be determined, if necessary, by a subsidiary survey on a grid basis.) Using regression equations based on the coefficients of correlation determined in the first survey, it is then possible to estimate the total yield of bark for the block as a whole.

Such methods have been used, for example, in forestry work in the U.S.A., and have been sometimes called "double sampling." Various other possibilities are of course open; recourse may be had to triple or quadruple or n-ple samples, so that this type of work may be suitably called the method of multiple sampling (which is, of course, to be carefully distinguished from multi-stage sampling). In one sense it is really an extension of the method of concomitant variations. The statistical relation between two (or more) variates is first determined by a preliminary sample survey or a series of such surveys. Estimates are then prepared for one of the variates by a second or subsequent survey, and estimates for the other correlated variates are then calculated with the help of the previously determined regression relations. A simple example occurs in crop-cutting experiments. In the Indian Statistical Institute the weight of green plants of jute or the weight of paddy immediately after harvesting are recorded on an extensive scale. In only a small fraction of cases (of the order of 10 per cent.) the jute plant is steeped in water, retted and the dry fibre extracted and its weight determined directly, or the paddy is dried, husked and the weight of rice measured separately. These auxiliary measurements serve to supply the regression relation between the weight of green plants of jute or the weight of paddy immediately after harvesting and the yield of dry fibre of jute or of husked rice, respectively, which can then be used to estimate the corresponding final yields from the more extensive weights taken immediately after harvesting. Such a procedure simplifies the field work enormously without any appreciable loss of precision in the final results.

Such methods, in which the estimates made in later surveys are based on correlations determined in earlier surveys, may perhaps be called "covariate sampling."

Planning of sample surveys

Coming back to the planning of sample surveys, the ultimate aim from the statistical point of view is, of course, to reduce the over-all or effective margin of error to the desired extent. It has been explained that in large-scale work this involves considerations of time, cost, and the human agency. These three factors are intimately connected, and are merely different facets of the same thing—namely, the plan or design of the survey. Any change in human agency, in general, would involve changes in the time programme, the total cost, and also (a point to be remembered) in the effective margin of error. In fact we learnt quite early the overwhelming importance of the human factor in the organization of statistical sampling on a large scale.

The over-all or effective margin of error does not consist simply of sampling variations, but also of errors of ascertainment arising from the fallibility of the human agency. W. Edwards Deming has emphasized this point on many occasions, and has given a comprehensive review in his paper on "Errors in Surveys" (*American Sociological Review*, Vol. IX, No. 4, August 1944, pp. 359–369). He gives a list of thirteen factors affecting the ultimate usefulness of a survey. I shall adopt a simpler classification for present purposes and omit differences arising from variability in response or changes in the universe, or the population or the field under survey. These sources of error are of particular importance in socio-economic or public opinion surveys and offer fruitful subjects for research. A good deal of work has been already done and is still going on in this field in the U.S.A. and U.K. In the Indian Statistical Institute we have also made a few studies, but on a comparatively small scale, as the great bulk of the Institute work has been concerned primarily with crop surveys, in which these problems are not of great importance.

Classification of errors

Very early it became clear that mistakes committed in the compilation of primary data and, to a less extent, at different stages of processing the material, were equally or even more important than errors of sampling. Continuous attention has had to be given, therefore, to this aspect of the problem. Faults in planning (including defects in the design and technique of sampling, the preparation of questionnaires and field schedules), as also mistakes in the final analysis or interpretation, belong to the purely scientific and technical level of the work, and have been kept out of the present discussion. The remaining sources of inaccuracy have been usually considered in the Institute under three broad heads described below.

Sampling variations, which have to be considered by familiar methods of theoretical statistics. The large sample theory (based on the normal distribution) has been naturally used most extensively.

Observed frequency distributions are, however, sometimes definitely non-normal in character, and special forms have been or are being investigated in certain cases. The logarithmic (for example, in crop yields) or square-root transformations (in certain economic and demographic studies) or truncated distributions (for example, in studying the correlation between weight of crop immediately after harvesting and weight of grain after drying) have been found useful. The subject, however, deserves and requires extensive investigations.

Recording mistakes have been usually considered under two sub-heads: mistakes which occur either through bias or personal equation of the observers or gross negligence or even deliberate dishonesty on their part; and mistakes which arise at the stage of compilation, classification, tabulation, computation, and final analysis and presentation of the material. Both types have been investigated in considerable detail in the Statistical Institute, and a great deal of attention is still being given to developing methods for controlling such recording mistakes.

Physical fluctuations. It has also been found that for every element (or quantity) sought to be estimated by the sampling method there exists a normal margin of physical uncertainty which is a characteristic feature of the element under survey. For example, it is believed that wheat increases in weight by as much as 4 or 5 per cent. by the absorption of moisture during the rainy season in a dry province like Sind. Traders, in fact, move the grain by railways at such times that the gain accruing from the increase of weight practically pays for the cost of storage and freight. In this case the exact meaning of the term "total production of wheat" has to be carefully specified. But even when this has been done, a residual margin of physical fluctuations of the order of probably 1 or 2 per cent. would still remain. It is clear that no useful purpose would be served by trying to reduce the sampling error to a value below the margin of such physical fluctuations.

Controls at the stage of statistical processing

Output and mistakes occurring at different stages of copying, compilation, or numerical computations have been studied in considerable detail. For this purpose, computational work has been broken down into a large number of jobs or items with standard specifications such as copying three-figure tables, adding four-figure quantities, squaring three-figure entries, preparing frequency tables with not more than ten classes, etc. For each item, standard rates of output have been worked out, as also permissible limits of rates of mistakes. For each item standard rates of payment have also been set up. A daily job account is kept of the item, time spent, and output for each computer separately, and these are punched on Hollerith cards and tabulated for the valuation of the total work done by each computer in each month.

Individual differences are also studied, which enables inefficient workers to be weeded out on an objective basis, and work to be distributed among different workers in a suitable way. (Some workers were found to have such high rates of mistakes that their net valuation was negative, showing that a premium would have to be paid to the Institute for employing them.) The advantage of the above system is two-fold. It supplies a scientific method for controlling mistakes at different stages of the processing of the primary material. It also supplies a sound basis for cost accounting, which is a characteristic feature of work in the Institute.

In the valuation of computational work it is necessary, of course, to take into consideration not merely the total output, but also the number of mistakes committed. The method of making deduction on account of mistakes is simple in principle. Each mistake involves a certain amount of expenditure in correcting it; and, in theory, the deduction made should be equated to this additional expenditure. In practice the matter is, however, complicated, but the subject is being studied, and attempts are being made to set up standard procedures.

Sub-samples in statistical analysis. In large-scale computational work it has been sometimes found convenient and useful to carry out the statistical analysis in the form of a number of sub-samples. The sample units are allotted consecutive serial numbers in the order in which these are located on maps or picked up for being included in the survey. It is possible therefore to divide the sample data into a number of independent random sets by choosing sample units with odd or even serial numbers, or with numbers ending in particular digits. The actual computational work and analysis are then done separately for each such randomized sub-set of the material. This has three distinct advantages. Firstly, it often enables dimensional results to be obtained very quickly, which is sometimes of great help to administrators. Secondly, a comparison of the results of different sub-sets often gives clues for the detection of gross mistakes in procedure or in calculations.

Finally, results for different sub-sets supply a very good idea of the over-all or effective margin of error.

Controls in mechanical tabulation. It may be mentioned here that during the last two years a great deal of the Institute work has been mechanized. The Institute has at present a full equipment of Hollerith eighty-column sorter, tabulator, and multiplier units with a battery of about fifty hand-operated punching and verifying machines, and a summary reproducing punch. In the Hollerith system each card is punched, and then passed a second time through a verifying machine operated by a different worker. With about fifty punching and verifying workers, the human factor becomes quite important. In the beginning there was some difficulty in getting the verifying work done with proper care. A simple but effective statistical control has been now introduced which is probably worth mentioning. A concrete example will make the method clear. Consider the procedure for checking the accuracy of punching of say 10,000 cards. A suitable number (say 100 or 200 or 500) of punched cards are withdrawn from the set at random. A dummy set of an equal number of test cards are punched deliberately with mistakes in assigned columns; and this second set is substituted for the first set at the appropriate places. The whole set of 10,000 cards is then verified. It is clear that, if the work is done properly, then the set of (100, 200 or 500, as the case may be) test cards must be rejected at the stage of verification in the exact order of their serial number. Besides the test cards it is possible and likely that other cards also would be rejected; but the test cards must come out in any case. This supplies a good foolproof check at the stage of verification.

Efficiency at the stage of processing. Generally speaking, the basic problem may be stated in the following way. A given volume of computational work (in the most general sense, including scrutiny of primary material, sorting, tabulation, statistical analysis, checking, etc.) is required to be done. The problem is to organize the processing work in such a way that it can be completed with maximum accuracy in minimum time and at minimum cost. The subject is important and fascinating, and attempts are being made to study it as far as possible along with the regular work of the Indian Statistical Institute. Valuable information has been collected and indications for future investigations have been secured, but it has not yet been possible to tackle the problem on fundamental lines for lack of resources.

Illustrative examples

I shall now try to give some idea of the kind of information which it has been possible to collect by the method of statistical sampling in recent years. It is quite impossible, of course, to give a detailed account of the numerous enquiries undertaken by the Indian Statistical Institute during the last five or six years. I have therefore made a selection of typical examples which are likely to be of interest outside India. The use of replicated networks of samples (in which information for each network is collected independently by different sets of investigators) has been a characteristic feature of the work in the Institute. It includes as a special case the same sample being surveyed twice or more often by independent investigators. Such methods have been used very successfully in furnishing estimates of the over-all margin of error, and I have intentionally laid stress on the use of replication in choosing my examples.

Crop surveys

This is the field in which the largest volume of work has been done in the Indian Statistical Institute. An account has been given elsewhere (*Philosophical Transactions*, B 584) of the general development of work which took place from 1937 to 1941, in which year a sample survey of the area under jute was carried out throughout the province of Bengal. The survey of jute acreage was repeated in 1942. Although by that time, owing to Japan's entry into the war, the food situation in Bengal had already become difficult, I failed completely to persuade the Government to extend the sample survey to cover the paddy crop in Bengal. The Bengal famine occurred in 1943. Since that year we have had the opportunity of carrying out a sample survey of both jute and rice crops throughout the province.

NB

Bihar Crop Survey. As already mentioned, a pilot survey had been started in only two districts, comprising about 8,000 square miles, in the *rabi* (winter wheat) season in February 1944. The scheme was rapidly expanded to cover the whole province, and a full-scale survey of *aghani* (winter rice) of 1944–45 season was carried out only a few months later.

TABLE 1

Bihar Crop Survey. Progressive reports on winter rice, 1944–45

Estimated area (in hundred thousand acres) under different crops.

Serial no.	Field work up to	Grids surveyed		Sampling fraction one in	Area in hundred thousand acres under			
		Number	Percentage		Rice	Pulses	Sugar cane	Potatoes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	October 17th	2,588	4·0	4175	133·35	29·55	—	—
2	November 2nd	14,361	22·3	752	135·37	30·65	3·72	—
3	„ 11th	19,813	30·8	545	140·70	31·28	3·74	—
4	„ 18th	25,934	40·4	417	141·71	30·31	3·94	—
5	„ 26th	32,312	50·3	334	140·89	29·77	3·87	—
6	December 4th	38,818	60·4	278	139·46	29·78	4·01	—
7	„ 12th	45,006	70·0	240	138·72	30·40	4·03	—
8	„ 21st	51,502	80·1	210	140·05	29·63	4·06	—
9	January 12th, 1945	64,260	100·0	168	136·50	29·03	3·97	1·12
	(Total area covered = 432·23) proportion =				31·58%	6·72%	0·92%	0·26%

The above table shows the actual progressive estimates which were submitted to the Government from time to time. It will be noticed that the first estimates were based on only 2,588 grids (or about 4 per cent. of the total number ultimately surveyed), which represented a sampling fraction of one in 4,175, and yet the estimates of the area sown with rice (133·35) and with pulses (29·55) were of right dimensional order and compare quite favourably with the final figures, 136·50 and 29·03 (in 100,000 acres), respectively. After receiving the first estimates of rice and pulses, the Government desired to have similar figures for the area under sugar-cane, which were submitted regularly from the second progressive report. At the last stage, at the request of the Government, an estimate of 1·12 (in 100,000 acres) was supplied for the area under potatoes.

The total geographical area covered in the survey was 432·23 (in 100,000 acres), so that the proportion of land was 31·58 per cent. under rice, 6·72 per cent. under pulses, 0·92 per cent. under sugar-cane, and only about 0·26 per cent., or one quarter of 1 per cent., under potatoes. This would supply a good idea of the wide range of the survey. It, however, scarcely needs mentioning that the percentage (but not the absolute) error would be naturally quite high for potatoes or sugar-cane which have comparatively small acreages.

Another point is worth explaining. Sowings of rice continue for a good length of time, possibly till the middle of November, depending on actual conditions of rainfall in different areas. In Bihar (as well as in Bengal) the rice crop is mainly rain-fed, and usually a certain proportion of marginal land is put under cultivation in the hope of a favourable distribution of rainfall. When the rainfall is not exceptionally favourable (as often happens) it is inevitable that some of the lands which in the earlier part or middle of the season are under a particular crop will go out of cultivation owing to lack of rain at the end of the season. The total area under rice therefore increases from the beginning to the middle of the season, and then usually decreases. For this reason the earlier estimates would often agree fairly well with estimates based on material collected at the end of the season.

Bengal Crop Survey. A brief description of the Bengal Crop Survey would be useful at this stage. The province of Bengal has been divided into about 1,100 "cells," each approximately 64 square miles in area. In doing this the boundaries of *mauzas* (broadly corresponding to villages, and roughly about one square mile in area) have been kept intact, so that each *mauza* (or village) lies entirely within a single cell. This has been done in order to facilitate the building up of estimates for higher administrative or revenue units such as *thana* (or police circle of 150 square miles on an average), sub-division (about 850 square miles) or districts (about 2,500 square miles), and finally the province as a whole (70,000 square miles).

Flexibility of the design. The design of the sample survey has naturally to take into consideration the intensity of cultivation or the importance of particular economic variates desired to be investigated in different regions. For example, in crop surveys it is legitimate to omit areas known to be under forests. In the case of particular crops like jute it is permissible and necessary to allot a comparatively small number of sample units to regions or cells where jute is known to be grown only in small quantities (when it is desired to obtain an accurate estimate of the total production of the crop for the province as a whole). The arrangement by which the whole province is divided into a large number of cells gives great flexibility in designing, as it permits unimportant cells to be left out of the survey altogether or to be allotted a comparatively small number of grids. The first stage in the design of the survey is thus to settle the size (area) and the number of grids to be allotted to the different regions or cells. For surveys covering a number of crops or a number of different elements it is often convenient to adopt a uniform density, or the same number of grids for each cell included within the survey. But this is a special case; in general, the number in each cell can be varied as desired.

In Bengal the total number of sample units allotted to each cell (of 64 square miles) is at present of the order of 100 for crop surveys. The position of each grid is located at random and marked on maps. In this way each *mauza* gets none or one or more random points. These random points are numbered serially as they are marked on the map, and a grid (of 2·25 acres for crop surveys) is located at each random point. All fields falling within the grid are subsequently surveyed by the field staff.

Two sub-samples. Within each cell (in which the act of randomization is carried out separately) the sample units, as they are located at random, are given consecutive serial numbers, so that the set of sample units or grids with even serial numbers and the set of sample units or grids with odd serial numbers form two independent, but inter-penetrating and random networks of sample units, each of which covers the same area. These two sets are allotted to different parties of field investigators, so that information for each set is collected independently. These two sets of data thus supply two independent estimates for each cell as a whole.

Duplicate grids. A further control is used in crop surveys as a routine measure at present. A certain number of grids or sample units are allotted to both networks so that information for such "duplicated" sample units is collected by both sets of field investigators. In the Bengal Crop Survey in 1946, for example, out of fifty-four grids allotted to each network of samples, fourteen are "duplicated" or common to both sets. A detailed comparison of the two sets of field records for these fourteen grids in each cell shows how far the field survey has been done with care. The field investigators know that certain grids are duplicated, but have no knowledge as to which particular grids have to be enumerated twice. The field programme is arranged in such a way that the two different parties of investigators are separated by at least two or three days' journey, so that there is no chance of the investigators copying the records from one another. This method has proved extremely useful in supplying a good control at the point of collection of the primary material.

It is worth mentioning briefly another control used in connection with duplicated (or sometimes replicated) grids or sample units which are enumerated twice (or more often) by different parties of investigators. In the crop survey the investigators are required to note the average height of the plant in each field. As the duplicated (or replicated) surveys are done at different times—sometimes with an interval of even two or three weeks—this supplies a good check. For example, cases have occurred in which the height of plants were recorded as being lower at the time of the later survey than the height recorded during an earlier survey. Such discrepancies can arise only through mistakes in identifying the fields, or through gross negligence or dishonesty on the part of the investigators. Such controls also serve the useful purpose of supplying an objective basis for the rejection of unreliable primary material.

Agreement between half-samples. Table 2 shows the two independent (replicated) estimates of crop acreages in Bengal during the three years 1943, 1944, and 1945. The design was that of two interpenetrating random networks of samples. The actual design of the survey was different in each year, but it is not possible to enter into these details. The two independent samples (A and B) are usually called half-samples as both together make up the complete sample. These might also have been called "double" samples; but this would have probably raised misapprehensions about cost in the minds of administrators.

course, entries are made by pure guesswork by unreliable investigators who want to avoid the trouble of going round to the fields. It must be remembered that conditions in which the crop enumeration has to be done in Bengal are particularly difficult. In summer the temperature would often go up to 110° F. or more; during the monsoon many of the roads are submerged; throughout the crop survey a large number of investigators suffer from malaria and other diseases every year. This makes it all the more necessary to have adequate controls at the point of collection of the material.

I am giving below a few tables to indicate the kind of material collected and nature of comparisons made in the Indian Statistical Institute on an extensive scale from year to year.

TABLE 3

Illustrative summary comparisons of duplicate crop records prepared by different investigators (A and B)

Province and zone under survey	Years of survey	Name of crop	Estimated acreage		Discrepancies (*A* − *B*) between the two records				Percentage to *A*	
					Actual		Sum			
			(*A*)	(*B*)	Positive	Negative	Algebraic	Absolute	Algebraic	Absolute
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Bengal 2 *thanas* ...	1937	Jute	355	385	103	133	−30	236	−8·5	66·5
Bengal 8 *thanas* ...	1938	Jute	3,584	3,646	466	528	−62	994	−1·7	27·7
Bengal 6 *thanas* ...	1944	Wheat	286	298	100	112	−12	212	−4·3	74·6
Bihar 6 *thanas* ...	1944	Gram	730	636	244	150	94	394	12·9	53·9
Bihar 86 *thanas* ...	1944	*Bhadoi* paddy	6,715	6,481	1,658	1,424	234	3,082	3·5	45·9

The above table gives a comparison of duplicated crop records prepared independently by two different sets of investigators called *A* and *B*. Cols. 4 and 5 give the two independent figures of total acreage under the same crop in the same geographical area. A detailed comparison of the two sets of records was carried out for each field separately. For example, a particular field may be shown as being under jute by the first party of investigators (*A*), but not under jute by the second party of investigators (*B*). In such cases the discrepancies *A* − *B* may be considered to be positive. When a field is shown under a particular crop by party *B*, but not by party *A*, the discrepancy *A* − *B* would be then naturally considered to be negative. If such discrepancies are added up for each individual plot, one would get the total positive or negative discrepancies. These are shown in cols. 6 and 7, and the point to be emphasized is that such absolute discrepancies are actually very large, and in the above table range from 27·7 per cent. to 74·6 per cent. So far as detailed crop records are concerned, it is quite clear, therefore, that the so-called complete enumeration cannot supply reliable results under conditions actually existing at present in Bengal or Bihar.

Many of the mistakes are, however, unbiased and tend to cancel out. The total algebraic errors are obtained by simply adding the positive and negative discrepancies, and are shown in col. 8. For example, in the first line of Table 3 the figure −30 in col. 8 is obtained by adding the positive and negative discrepancies in cols. 6 and 7, and is of course also simply the difference between the two figures given in cols. 4 and 5 respectively. In comparison with the absolute discrepancies shown in col. 9 it will be seen that algebraic discrepancies are proportionately much smaller, owing to the cancelling out of positive and negative mistakes. In other words, results of complete enumeration of crops as carried out at present in Bengal or Bihar have exactly the same qualitative kind of statistical reliability as results based on sample surveys, with the important difference that in the so-called complete enumeration (as usually conducted without any superposed sampling controls) there is no possibility of estimating the margin of error. This is a conclusion of the greatest practical significance.

Two illustrative examples of a detailed comparison, plot by plot, of duplicated crop records are given below. Table 4 refers to material collected in *mauza* (village) Kazikandi in P.S. Goalundo

TABLE 2

Bengal Crop Survey. Half-sample comparisons, 1943–45

Year	Number of grids surveyed			Area under crops in thousand acres			Difference (*A* − *B*)		Standard error of difference	Fisher's *t*
	Sample (*A*)	Sample (*B*)	Combined	Sample (*A*)	Sample (*B*)	Combined	Actual	Percentage		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
					Jute crop					
1943	29,676	29,676	59,352	2,759	2,757	2,758	2	0·1	100	0·02
1944	30,487	30,037	60,524	2,150	2,056	2,106	94	4·45	50	1·87
1945	53,504	52,623	106,127	2,512	2,528	2,520	− 16	0·8	*	—
					Aus (monsoon) rice					
1943	29,676	29,676	59,352	6 807	6,923	6,865	−116	−1·7	446	0·26
1944	30,457	30,037	60,524	7,815	7,942	7,873	−127	−1·6	90	1·41
1945	53,504	52,623	106,127	6,966	6,805	6,864	161	2·3	*	—
					Aman (winter) rice					
1943	31,216	31,215	62,431	23,840	24,044	23,942	−204	−0·8	703	0·29
1944	50,501	50,107	100,608	22,491	21,903	22,201	588	2·7	550	1·07
1945	46,148	45,971	92,119	20,970	21,202	21,087	−232	−1·1	103	2·26 †

* Error calculations for 1945 were not completed at the time of writing.
† Significant at 5 per cent. level.

The two crop estimates in thousand acres based on the two independent samples (*A* and *B*) are shown in cols. 5 and 6 respectively, and the pooled estimate in col. 7. The difference between the two estimates $A - B$ in thousand acres is shown in col. 8, and the same difference expressed as a percentage of the combined value given in col. 7 is shown in col. 9. The standard error of the difference calculated from the samples is given in col. 10, and Fisher's t in col. 11. This table shows the kind of results which are actually obtained in practice. I should like to note, however, that the field survey in 1943 had to be organized at very short notice and under great difficulties (owing to the incidence of the Bengal famine), and supervision was probably not quite adequate; the close agreement between the two half-samples may be, therefore, to some extent spurious.

Discrepancies in crop enumeration. Since 1937, when work was started by the sampling method on a very small scale, the relative accuracy of the results obtained by a so-called complete enumeration and by the sample survey respectively have been the subject of acute controversy in India. From the very beginning attempts were therefore made to investigate the reliability or otherwise of crop enumeration done by ordinary field investigators in actual practice. The method adopted has been to carry out independently twice (or more often) complete enumerations of crops on fields in the same village or region by entirely different sets of investigators. If crop enumeration can be carried out with complete accuracy, then the two sets of records should be in perfect agreement. Certain discrepancies are, however, introduced by the fact that the two surveys have necessarily to be carried out one after the other in order that there is no chance of one party of investigators copying from the records prepared by the other party. If the first survey is carried out before sowings are completed, it is possible that certain fields which were uncultivated at the time of the first survey might have been brought under cultivation by the time the second survey is made. Or if the second survey is made rather late in the season, it is possible that some of the fields having standing crops at the time of the first survey might go out of cultivation at the time of the second survey for lack of rainfall or other causes. Such discrepancies can, however, be usually distinguished from a knowledge of crop conditions in relation to the two dates of survey.

A great deal of material of this nature has been compiled, year by year, since 1937. Even a cursory examination of the material leaves no doubt that very large discrepancies occur at the stage of crop enumeration. Some of the mistakes are genuine, in the sense that the investigators actually fail to distinguish between different crops, or make wrong estimates of the proportion of the field under different crops. Mistakes due to gross negligence, however, also occur; and sometimes, of (an administrative unit) in Bengal in 1943. In this village 332 fields were surveyed by investigator *A* on August 14th, 1943. He noted the name of the crop (or mixture of crops) growing on each individual field. A second complete enumeration was made by investigator *B* about a fortnight later, on September 2nd, 1943, who also noted independently the name of the crop or mixture of crops growing on each individual field. Two records were thus available for each field, and can be shown in the form of a two-way table as in Table 4.

TABLE 4

Bengal Crop Survey, 1943. *Comparison of duplicated complete enumeration in P. S. Goalundo,* mauza *Kazikundi*

(*B*-survey September 2nd, 1943)

		Jute	*Aman* rice	Jute–*aman*	No crop	Total
A-survey August 14th, 1943	Jute	4	15	4	3	26
	Aus rice	4	12	1	4	21
	Jute–*aus*	17	66	2	9	94
	Jute–*aus*–*amam*	—	2	—	—	2
	Aus–*amam*	1	—	—	—	1
	No crop	37	45	4	102	188
	Total	63	140	11	118	332

If the crop enumerations made by the two investigators, (*A* and *B*) were in complete agreement, then all fields shown as being under jute by investigator *A* would also be shown under jute by investigator *B*, and vice versa, so that entries would occur only in the diagonal cells. A glance at Table 4 would show that the actual position was entirely different. For example, according to investigator *B* there were altogether 63 fields under jute on September 2nd. According to investigator *A*, who had surveyed the same identical fields a fortnight earlier, apparently only four were growing jute, four *aus* (monsoon) rice, seventeen had a mixture of jute and *aus* rice, one field had mixture of *aus* (monsoon) and *aman* (winter) rice while no fewer than thirty-seven fields were without any crops at all. Discrepancies are equally striking for other crops. In fact out of 332 fields surveyed, the two investigators were in agreement only in regard to four plots, which both recorded to have been under jute, and also in regard to 102 fields, which were shown by both as having no crops at all. In other words, in only 106 out of 332 entries was there agreement between the two independent crop enumerations. This is clearly unsatisfactory, and shows that either one or both the investigators had failed to do their work with reasonable care.

TABLE 5

Bengal Crop Survey, 1943. *Comparison of duplicated complete enumeration in P. S. Chuadanga,* mauza *Monirampur*

(*B*-survey August 10th, 1943)

		Aus	Jute–*aus*	None	Total
A-survey June 28th, 1943	Jute	1	—	1	2
	Aus	123	2	8	133
	Jute–*aus*	—	3	—	3
	None	7	—	189	196
	Total	131	5	198	334

A more satisfactory example is shown in Table 5 for another pair of investigators working in Bengal in the same year. In this case out of 131 fields recorded as having *aus* (monsoon) rice by investigator *B* on August 10th, 1943, no fewer than 123 had been shown as having rice also by investigator *A* during the earlier survey on June 28th, 1943. Out of five fields shown as having both jute and *aus* (monsoon) rice by investigator *B*, three were shown so in the earlier survey, while two fields were shown as having only *aus* rice by investigator *A*. This is quite possible, as *aus* rice is sown earlier, and these two fields might have been sown with jute after the first survey was over.

TABLE 6

Bihar Crop Survey, Bhadoi, 1944-45. Comparison of two independent estimates of p *(proportion of land under* bhadoi *rice in each individual plot) by two parties of investigators.*

District, Hazaribagh; Thana, Giridih; No. of villages, 86

Second survey: Anna estimates of proportion of land under rice during 2nd survey between Aug. 6th and Oct. 12th \ First survey: Anna estimates of proportion of land under rice during first survey between August 3rd and September 29th, 1944	Zero	1-anna	2-anna	3-anna	4-anna	5-anna	6-anna	7-anna	8-anna	9-anna	10-anna	11-anna	12-anna	13-anna	14-anna	15-anna	16-anna	Total
Zero	23,988	72	116	29	116	26	51	14	108	10	33	13	68	15	31	24	4,307	29,021
1-anna	87	6	8	3	2	—	1	—	3	—	—	1	1	—	—	3	33	148
2-anna	115	6	12	3	4	—	1	2	9	2	—	—	2	1	—	2	79	238
3-anna	32	6	3	—	2	—	—	—	3	—	5	—	1	—	—	—	24	76
4-anna	129	6	9	2	16	1	7	1	9	—	4	1	2	—	2	—	102	291
5-anna	14	1	1	1	—	—	—	—	1	—	1	—	1	—	—	—	17	37
6-anna	59	—	3	1	6	—	3	1	5	1	—	3	2	2	—	—	56	142
7-anna	23	—	—	—	3	—	—	—	1	—	1	—	—	—	—	—	19	47
8-anna	130	4	3	1	7	—	5	—	13	1	7	1	4	—	5	1	157	339
9-anna	9	—	1	—	2	—	2	—	1	—	1	—	—	—	—	—	13	29
10-anna	44	—	3	3	3	—	2	—	3	1	8	2	3	1	2	—	77	152
11-anna	18	—	—	—	2	2	1	—	—	—	—	—	—	—	—	—	13	36
12-anna	63	—	—	1	5	—	3	1	6	—	1	—	4	1	2	—	109	196
13-anna	7	1	—	—	—	—	—	1	1	—	1	—	—	—	1	—	26	38
14-anna	43	—	2	—	—	—	—	—	5	—	2	—	4	—	1	3	112	172
15-anna	21	—	—	—	3	—	1	—	2	—	1	—	3	3	4	1	121	160
16-anna	3,721	27	25	11	65	10	43	10	113	18	70	16	82	34	109	82	20,635	25,071
Total	28,503	129	186	55	236	39	120	30	283	33	135	37	177	57	157	116	25,900	56,193