EXPERIMENTAL LAND UTILISATION SURVEYS IN CADASTRALLY UNSURVEYED AREAS THROUGH DIRECT PLOT TO PLOT OBSERVATIONS, BIHAR 1956-57

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1. Object

1.1. For land utilisation surveys based on a physical plot to plot observation of the fields, the use of cadastral survey maps showing the plot boundaries is essential, both as a frame for the selection of sample plots as well as for the identification of selected plots on the ground for purposes of actual enumeration. The investigator has to identify each plot comprising individual sampling units and enumerate the proportions of the plot area under different crops and /or other kinds of utilisations, either by actual measurements or by an eye-estimation. As early as 1937, the Indian Statistical Institute had fully investigated into the adequacy of the eye-estimation returns and found that the eye-estimated proportions gave unbiased averages, the inaccuracies in individual plots balancing out when averaged over a large number of plots enumerated by a large number of investigators. This method has, therefore, been adopted in all the surveys conducted by the Institute on a provincial scale since 1942.

1.2. If villages are selected at random, they may either be completely enumerated or a number of fields may be selected in the second stage within each of them. In either case, a diagrammatic sketch is obviously essential for identifying each field in order to avoid duplications or gaps, and to ensure that the survey is amenable to a subsequent check.

1.3. In connection with the National Sample Surveys over the length and breadth of India, we have been faced with the problem of dealing with regions which have not been cadastrally surveyed as yet. For these areas village maps showing the plot boundaries are not available, the smallest administrative units for which maps are uniformly available being a Tehsil, a Taluk or a Thana. It is guessed that about 15% of the Indian Union has not yet been cadastrally surveyed.

1.4. An investigation was made if a rough pictorial diagram of the relative position of the plots (not true to scale) could be prepared for such villages, so that each individual field shown on the sketch could be numbered and identified on the ground. A small scale experiment was undertaken in the neighbourhood of Giridih in 1951

and a trained 'Amin' (cadastral survey assistant) as well as a number of ordinary investigators without any such training were asked to prepare a rough sketch of a neighbouring village showing the layout of the fields with the use of only a measuring pole. The result was most disappointing. The sketches prepared could not be used for identifying the fields on the ground. Even the trained assistant proved no better than the untrained ones in this respect. It is possible, of course, to make a cadastral survey of any village with the help of standard survey instruments. But the procedure is costly and apart from cost, in such surveys where sample villages are not fixed a change of the sample villages from round to round of the survey would make such a procedure hardly practicable.

1.5. There are on the other hand large areas where even the skeleton maps showing boundaries of a village are not available. In forests and hilly areas, the boundaries are often not even approximately identifiable. The borders of such villages are only vaguely known, and the exact line which demarcates two adjoining villages is not distinguishable. If the boundaries of a village are broadly known, and if the number of cultivated fields are small, it may sometimes be possible to measure out the sides of each individual field with a measuring rod or by walking round it and counting the number of steps. But great precaution has to be taken to prevent duplications and to ensure that there are no gaps. Attempts have, therefore, been made to try out alternative procedures by which unistage locations in space into such strata, even if approximate, could be performed in practice. This note deals with some of the experiments conducted in the district of Hazaribagh (Bihar) in the year 1956-57.

2. A PRELIMINARY TRIAL FOR THE LOCATION OF RANDOM POINTS ON THE GROUND

2.1. *Experimental procedure.* In order to have a unistage sampling over a given area representing a village or a larger area comprising a group of villages, the first step is to locate a point at random in space with a given set of coordinates x and y along two directions chosen as the axes of reference. Once the investigator can reach a point x, y without using the cadastral map, the choice of a suitable sampling unit should not be difficult.

2.2. The Survey of India (SI) maps in a scale of one inch to the mile are available for the whole of India in the shape of squares called 'grids' representing a sector of 15 minutes of longitude and 15 minutes of latitude with approximately an area of 256 sq. miles. In these maps the roads, rivers, mosques, old buildings, and many other salient landmarks are indicated. The names of important places are dotted here and there, but the boundaries of either the Tehsil, Thana, Taluk or of the villages are not shown therein. These maps were available for the whole of the Indian Union including the cadastrally unsurveyed areas. It was, therefore, decided that these should serve as the only guide to the investigator who unaided by a cadastral map showing the village and plot boundaries, would proceed to any point x, y parallel res-

pectively to East-West and to North-South directions. He would take his bearings with reference to a bend in the roads or of a river, a junction of two roads or any other salient point shown on map.

2.3. *Coverage.* A compact block of approximately 100 sq. miles around Giridih (Bihar) as centre was chosen for conducting a preliminary trial for the location of random points with the help of SI maps alone. This area was partly hilly, partly under forests, but the major portion comprised of tracts with highly terraced cultivations. The SI maps were very old, prepared at a time when this district was very little developed. As a result, very few roads and other landmarks have been indicated in these maps. Location of a point with reference to these maps was thus made doubly difficult. Besides, the hills and forests and the undulating slopes added to the difficulty. This tract was therefore considered to be typical of somewhat difficult regions that were usually left unmapped. Altough this area was cadastrally surveyed, *investigators were not issued the cadastral survey (CS) maps, who were to assume as if it was not* cadastrally surveyed.

2.4. *Operations.* Eight points were located at random on the "block" map (i.e. relevant sections of the SI map comprising the block) in the scale of one inch to the mile each of which was to be located on the ground by each of eight investigators. The location of a point was made with the help of a pair of random numbers to represent coordinates x, y along two chosen axes of references OX and OY at right angles to each other, the origin O being chosen outside the block in such a way that OX and OY did not pass through the block and the block remained entirely within the first quadrant. These points were marked on the block map, a copy of which was also furnished to the investigator in addition to the coordinate values of each point. The investigator equipped with the block map showing the roads, canals and other salient marks but no village boundaries or even the Thana boundaries, was asked to locate each of these points on the ground. He was to locate these points as best as he could, by reading off their bearings in relation to one or more of the salient points shown on the map. The shortest (crow-flight) distance of the sample point from the salient point was measured on the map correct to the tenth of an inch, representing 528 ft. or 8 chains on the ground. The angle which the line joining this salient point and the sample point makes with the North-South line was determined in degrees with the help of a protractor.

2.5. *Traverse from a salient point to the sample point.* Starting from the salient point the investigator was then to proceed to the sample point in a crow-flight route, the required distance to be covered being in terms of his steps which were first standardised by an initial practice. To standardise the steps seven different trials with an average distance of 575 ft. were repeated by each of the eight workers. The average length of steps in each trial and the overall standard measure for each individual has been given in Table 1 along with the coefficients of variation. It appears that

although the steppings considerably differed from worker to worker, the variations within an individual are reasonably low.

TABLE 1. MEAN LENGTH OF STEPS BY WORKERS IN A TRAVERSE OF 575 FEET (AVERAGE)

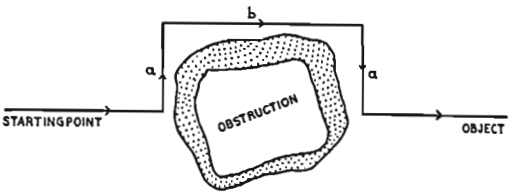
worker number	average length of steps in feet for each traverse								
	no. 1	no. 2	no. 3	no. 4	no. 5	no. 6	no. 7	mean	c.v.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	2.68	2.59	2.67	2.68	2.53	2.59	2.63	2.62	2.2%
2	2.44	2.40	2.45	2.54	2.46	2.49	2.45	2.46	1.8%
3	2.71	2.70	2.66	2.71	2.71	2.74	2.69	2.70	0.9%
4	3.01	2.95	3.00	3.00	2.94	2.93	2.65	2.93	4.3%
5	2.52	2.37	2.50	2.48	2.47	2.49	2.40	2.46	2.2%
6	2.80	2.70	2.76	2.69	2.67	2.76	2.71	2.73	1.7%
7	2.18	2.09	2.14	2.14	2.00	1.98	2.13	2.09	3.6%
8	2.74	2.67	2.78	2.78	2.77	2.77	2.88	2.77	2.2%
all	2.64	2.56	2.62	2.63	2.57	2.59	2.57	2.60	2.6%

2.6. Once the standard measure of an individual investigator is known, it is easy to convert the distance in feet to be covered on ground as observed from the map to the number of steps that he has to take, assuming that he can all along proceed in a straight line and with more or less uniform steps.

2.7. *Direction finding with the help of a magnetic compass.* In order to be able to proceed in the correct direction, he has now to sight a distant land-mark, a tree or a building in his line of vision through the sighting slit of the magnetic compass (with which he is provided) hold in a manner such that the needle points to the desired angle. He should then travel in a straight line until he reaches that object. If there are obstructions to direct vision right up to the sample point, he has to choose an intermediate target and proceed in a number of stages until he reaches his final destination, namely, the sample point.

2.8. Whenever there are physical obstacles like water, house sites or tree clumps, through which it is either impossible or extremely difficult to pass, he has to deviate either to the right or to the left until he finds a clearing parallel to his original direction of traverse, keep a count of steps 'a' by which he has actually deviated perpendicularly, traverse forward until he clears the obstruction, keep a count of these forward steps 'b', make a perpendicular counter deviation equal to the steps he had taken earlier, i.e., 'a' steps and come back in line with his original direction. He is not to count the number of steps corresponding to the arm 'a' in either direction,

while the obstruction itself (an utilisation) is to be credited a length 'b' steps along the general traverse. This is being illustrated in the diagram below.



At repeated intervals, he has to sight through the magnetic compass and check up if he was traversing in the correct direction.

2.9. *Identification of the sample point after it is located on the ground.* On reaching the sample point, i.e. when a traverse of the required number of steps was completed in the direction read from the map, he was to mark it by a peg and also to note down its distance (in steps) along with its direction (degree made with the N-S line with the help of the compass) from more than one nearly-permanent land-marks (a tree, a telegraph post and such others) and the nearest household. The name of the owner of this household was also to be noted. These were the landmarks which would enable the Inspector to reach and identify the point x, y actually spotted by him on the ground.

2.10. *Verification of the sample point as spotted on the ground.* In order to check up how closely the sample point spotted on the ground agreed to the 'true' point which corresponds to the coordinates x and y on the SI map, the Inspector was to identify the spotted point with the help of a CS map (village map) and ascertain what position the spotted point on ground occupied on the map, i.e. its approximate location within the cadastral plot. A verification of the point x, y located on the ground by investigator could then be made by a projection of the x, y point from the SI map to the CS map of a scale of sixteen inch to the mile. The deviations between these two markings could then be read off.

2.11. It is obvious that the location of a point by the above procedure is bound to be very rough. The preliminary trials were carried out in the month of June when the rains had started in earnest, while the topography as already stated was extremely difficult to negotiate. The agreement between actual location and its theoretical position was therefore expected to be extremely poor. The following results indicate, however, that the position is not utterly hopeless as was feared. In fact, the range of deviations gives credit to the performance of the investigators. It has to be remembered that in traversing, he had not only to by-pass obstacles, but had for

the most of the time to walk across standing crops and water-logged areas. It is extremely difficult for one to go on counting his steps all the time and remain always on the alert. Some of them took a number of stone-chips in their pockets and at each hundred steps dropped out one of them and thus kept a check on their count. The results of this preliminary trial are given in Table 2.

TABLE 2. AVERAGE DEVIATION (IRRESPECTIVE OF THEIR DIRECTIONS) OF THE POINTS LOCATED BY THE INVESTIGATOR ON THE GROUND FROM THEIR 'TRUE' POSITION MEASURED IN FEET

worker number	deviations in feet for individual sample points								
	1	2	3	4	5	6	7	8	average
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	162	65	90	243	329	1188	10	65	270.1
2	247	348	95	230	137	515	538	182	286.5
3	202	205	98	1002	286	—	—	154	324.5
4	181	252	30	654	290	1676	100	64	405.9
5	330	510	72	535	110	2482	495	300	606.8
6	370	572	54	268	365	2083	250	188	631.2
7	580	92	84	748	402	1742	494	—	591.7
8	383	70	90	238	207	852	68	81	256.5
average deviation	306.9	264.2	76.6	492.2	277.0	1630.1	280.6	147.7	422.0
average length of traverse*	757	3371	2231	981	1942	6712	6222	4762	3454
percentage deviation	40.6	7.8	3.4	50.2	14.3	24.3	4.5	3.1	12.2

* Distance traversed from a salient point to sample point.

2.12. From col. (10) of Table 2 it will be seen that the average deviations from the 'true' point range from 270 ft. to 631 ft. for individual investigators, with an overall average of 422 ft. The average length of total traverse one had to cover in reaching a sample point after starting from the nearest salient point has been given in feet at the foot of the table. The overall percentage of the distance deviated to the total length traversed is of the order of 12.2% which may be considered to be satisfactory. It should be noted further that the mean deviation does not take account of the direction towards which the investigator has deviated. The number of cases by which the investigators have deviated into one or other of the four quadrants, N-E, N-W, S-W, S-E about the true sample point were obtained as 12, 12, 22 and 14 respectively. For some unknown reason there is somewhat more crowding of the located points into the third, i.e. the S-W quadrant. The experiment on the whole indicates that with proper training and practice and with

improved instruments under better weather and topological conditions, location of random points in space without the help of cadastral survey maps can be made with a reasonable approximation.

3. First experiment on land utilisation survey with and without the help of cadastral survey maps

3.1. The results obtained from a preliminary trial on the location of points in space unaided by cadastral plot-wari maps, with the help of only a magnetic compass and the SI maps and reckoning the distances traversed by counting the steps, were encouraging.

3.2. A regular experiment was thereafter planned to compare the land utilisation estimates obtained from a sample with units located approximately in space without using CS maps against estimates obtained from a sample with units identified and located with reference to the CS maps. The following schemes were then drawn up using different units of sampling in a compact block of approximately 224 sq. miles comprising portions of the Police Stations of Bengabad, Giridih and Gande in Hazaribagh district.

schemes	survey equipments	period of survey			
		July	August	early September	late September
1. a two-stage sample with 30 villages in the first stage and					
(a) three "clusters" of 30 plots within the selected villages as second stage units	CS map	team 1	—	team 2	team 1
(b) three "line"-units of length 220 yds. within the selected villages as second stage units	magnetic compass and no CS maps	team 2	—	team 1	team 2
2. a unistage sampling with L-shaped 'line'-units, each arm of the L-shaped units being of length 220 yds.	magnetic compass, SI map, but no CS maps	—	teams 1 & 2	—	—

3.3. In the first round of July, Team 1 surveyed a sample of 30 villages and Team 2 surveyed the sample of 'line'-units in the same villages. In the second round of August, both the teams worked in Scheme 2 with unistage 'line'-units. In the third round of early September, the teams interchanged their work for Scheme 1, Team 1 taking up the 'line' survey and Team 2 enumerating the cluster units. In

the fourth round of late September the teams again interchanged their work, Team 1 going to the 'cluster' survey and Team 2 enumerating the 'line'-units. Thus in Scheme 1 all the 30 villages were visited six times, thrice for a 'line' survey and thrice for a 'cluster' survey. Cadastral plot-wari maps were used by the workers in Scheme 1(a) only. The operational procedure was as follows.

3.4 *Scheme* 1 (a) : *Enumeration of "clusters" within a village with the help of village (CS) maps.* Within each village selected with a probability proportional to the geographical area, 3 clusters of 30 plots each were drawn with a probability proportional to the size (area) of the clusters. A sample of 10 villages with 30 clusters was allotted to each investigator, three investigators constituting one team. Enumeration of the proportions of area under the various land utilisations was made for each plot according to the usual procedure.

Scheme 1(b) : *Enumeration with 'line'-units within a village without the help of village maps.* The villages surveyed in Scheme 1(a) were simultaneously visited by one team for 'line' survey, when the other team was carrying out a cluster survey. But unlike the cluster units in Scheme 1(a), the "lines" sampled during three different visits under Scheme 1(b) within the same set of villages could not be made exactly identical. It was impossible in this case to fix up the same point as origin and arrive at the identical sample points from which the 'line'-units started. This is true both for Team 2 in its own two rounds of July and late September as well as for Team 1 which had only one visit in early September.

For a 'line' survey, the investigator was to locate three points at random within each village using three pairs of random numbers as coordinates with the East-West and North-South lines as the axes of reference.

As there were no village maps, the worker was to go by the name of the village. By reconnoitering round the village and by making personal enquiries, he had to gather to the best of his ability, a broad idea about the shape and dimensions of the village. The procedure adopted for the location of Sample units was as follows :

"Proceed approximately to the S-W corner of the village and fix up a point 'O' such that the E-W line (X-axis) and the N-S line (Y-axis) passing through O, fall entirely outside the village boundary and do not pass through the village, i.e. the entire village lies exclusively in the first quadrant. This has to be done by ascertaining the village boundaries through personal enquiries and a preliminary survey round the village.

After a point x, y is located by walking x-steps due East and y-steps due North, a length of 10 chains (one furlong = 220 yds. = 660 ft.) starting from this point and at one of the eight directions, namely, E, W, N, S, N-E, S-E, N-W, S-W chosen at random, has to be measured out on the ground and enumerated. The magnetic compass should be used for determining the directions of the traverse."

The coordinates for location and the length of the 'line'-unit was to be reckoned in the worker's standardised steps, the equivalent of his steps in feet being entered at the top of the schedule. The procedure of locating the point x, y was same as that adopted in the preliminary trials described in the earlier paragraphs. A 'line' was to be rejected and replaced only when more than half of its length fell outside the village boundaries.

4. 'Crop' (land utilisation) enumeration

4.1 Starting from the located point x, y the investigator was to proceed in the chosen direction in a perfect straight line up to 220 yds., i.e. its equivalent in his own steps. He was to traverse this 'line' across fields and *ails* in a bee-line and in passing, note and record the number of steps he has to take through the various land utilisations. The same crop will lie on his right as well as his left whenever he traverses across one utilisation patch. If he crosses an *ail*, half the *ail* width was to be credited to each of the utilisations on either side of the *ail*. If he travels along an *ail*, the 'crop' belonging to the nearer plot should be taken into account. If he passes exactly through the mid-*ail*, half the length should go to the 'crop' on the left and half to the 'crop' on the right. When he traverses across a patch of mixed utilisation, the whole length of intercept should be credited to both the components. When the requisite steps are counted, the total of detailed 'crop' intercepts which he has entered in the prescribed land utilisation form (specimen appended) should obviously add up to the equivalent of the full length of the line-unit in terms of his standard steps, the intercepts through 'mixed' utilisation being however counted only once.

5. Scheme 2 : Unistage sample of 'line'-units with the help of SI maps and a compass, but without using the CS maps

5.1. During the month of August, both the Teams 1 and 2 were diverted to Scheme 2 for a unistage sampling with 'line'-units located at random in space by a method adopted in the preliminary trials described earlier.

5.2. The investigator was furnished with a block map in the scale of one inch to the mile, a magnetic compass, a protractor, a divider and a scale. No village maps were to be utilised. Each investigator was to locate 10 points scattered over the entire block at random with the help of a compass and by counting of steps, taking his bearings with reference to one or more salient points or 'alamats' shown on the block (SI) map. After a random point p (x, y) is located, he was to note down, as in the preliminary trial, the detailed landmarks with reference to permanent objects such as a household, a tree, a telegraph post, etc. so that a checker could subsequently identify it for verifications. It may be noted here that in the trial survey as well as in Scheme 2 all the sample units were subsequently verified by the Inspecting staff with the help of CS maps. The deviations from the "true" sample point as noted on inspection have been analysed and the results are given in Table 3 below,

where the distribution of the Sample units are given in intervals of percentage deviations, the deviations being expressed as percentages to the actual distance traversed by the investigator in moving from a salient point to the sample point. From col. (10) it will be seen that percentage deviation falls as the traverse length increases, the overall mean percentage being 13.1%. Such deviations, provided they were not due to deliberate negligence, any unconscious bias on the part of the investigator should ultimately balance out.

TABLE 3. DISTRIBUTION OF SAMPLE POINTS BY LEVELS OF PERCENTAGE DEVIATION: THE DEVIATIONS BEING MEASURED FROM THE POINT LOCATED BY THE INVESTIGATOR ON THE GROUND FROM ITS 'TRUE' POSITION AND THEN EXPRESSED AS PERCENTAGE TO THE TRAVERSE DESCRIBED BY HIM BETWEEN THE SALIENT POINT AND THE SAMPLE POINT (58 POINTS IN A COMPACT BLOCK OF 224 SQ. MILES OUT OF 60 POINTS ATTEMPTED)*

length of traverse in (000) ft.	frequency by the percentage of deviations to total traverse								mean p.e. deviation
	0%-5%	5%-10%	10%-15%	15%-20%	20%-25%	25%-50%	above	total	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
below 2			2	2		3	3	10	31.05
2-4	3	3	5	4	3	3	1	22	19.15
4-6	4	2	1	1		1		9	10.85
6-8	3			2	2			7	12.71
8 and above	4	2	3		1			10	8.40
all	14	7	11	9	6	7	4	58	13.14

* S.U. No. 10 (Investigator 1)—deviation could not be measured for want of CS map.

5.3. Starting from this point p (with coordinates x, y) he was then to proceed to one of the eight cardinal directions N, S, E, W, N-E, S-E, N-W, S-W chosen at random (specified in the sample list furnished from the office). After traversing the equivalent steps corresponding to 220 yds. up to 'A', he was to turn at right angles either towards his 'right' or towards his 'left', (when facing the line up) according to specification laid down in advance. In this perpendicular direction, he was to traverse another length of 220 yds. up to 'B' and thus describe an L-shaped track 'PAB'. The procedure for filling in the land utilisation schedule was the same as adopted in Scheme I(b). Lengths of the 'crop' (i.e. utilisation) intercepts were noted in terms of steps.

5.4. In this scheme which called for travelling over long distances, the investigators were supplied with a bicycle which he could use only up to his chosen "salient point", where he had to leave his wheels and proceed on foot in order to be able to measure his traverse in terms of his 'steps'.

6. Results

6.1. In Schemes 1 and 2, three types of samples using three different sampling units were obtained as follows :

(a) clusters of 30 plots within the selected villages,

(b) 'line'-units of length 220 yds. within the selected villages,

and (c) unistage line-units (with two arms of 220 yds. each, at right angles to one another) within the block.

6.2. For Schemes 1(a) and 1(b), there were three visits giving three samples corresponding to three different time-phases, while Scheme 2 was carried out only for one round in the month of August. It may be noted here that the rains this year were unusually late and when it started it was incessant and continued for such a long time that many of the fields were flooded. This delayed the sowing operations in many places. Full sowings were not therefore over within the month of July, and its progressive increase can be traced even after the end of August.

6.3. The true picture is revealed from the series of progressive estimates obtained from each monthly round split up into two fortnightly sub-samples shown below in Table 4. It will be seen that the percentage of area under paddy cultivation goes on increasing even up to the first half of September.

TABLE 4. PROGRESSIVE ESTIMATES OF THE PERCENTAGE OF LAND UNDER PADDY CULTIVATION AS PER SCHEMES 1(a), 1(b) AND 2

period of survey	number of sampling units		percentage of area under Aman paddy	
	(a) cluster	(b) line	(a) cluster	(b) line
(1)	(2)	(3)	(4)	(5)
1/7—16/7	6	9	0.75	1.22
17/7—31/7	24	21	7.10	7.00
1/8—16/8*	×	22	×	17.16
17/8—31/8*	×	37	×	20.08
early September	30	30	26.03	21.43
late September	30	30	29.57	24.07

* unistage 'line' sampling

6.4. A consistent underestimation by the samples using 'line'-units is revealed in cols. (4) and (5) of Table 4. This tendency of underestimation in line-grids compared to cadastral plot sampling (area-units) was also detected in our early experiments of 1945 in the same area (Sengupta, 1956). In both these experiments the 'crop'-area of a field was defined as the total area extending up to the mid-line of *ails* or footpaths surrounding the field. The *bunds* or footpaths do not actually grow any crop on them, while there is usually a small strip of barren land lying between the actual crop front and the *bunds*. This is mostly due to trampling on the

outskirts of the field by men and animals. The investigators were instructed to include this strip as well as half the *bund* width in measuring a crop intercept. But this instruction may not have been strictly followed. The area was highly undulating with terraced cultivation all over and the *bunds* were unusually wide, slanting down to the field level on either side often making the base much wider than at the top. Such *bunds* of considerable width may have been easily treated as independent fields and returned as fallow. On the other hand, as a result of gradual fragmentation, a cadastral plot has often been sub-divided into a number of 'fields' tending to increase the proportion of area under footpaths and *bunds*.

6.5. The question of the allocation of *bund* area has, therefore, to be seriously considered and the operational procedure for the enumeration of line-units has to be thoroughly studied and carefully laid down. It will be interesting to note that the proportion of area commanded by *ails* of the cadastral plots is guessed roughly to represent 4%–5% of total geographical area. The order of underestimation observed in both the experiments suggests that this may be one of the factors that lie at the root of the observed underestimation.

6.6. Leaving out the sample surveyed in visit No.1, the estimated percentages of land under paddy cultivation along with their sampling errors based on visits 2 and 3 were worked out and the results are being shown for Schemes 1(a) and 1(b) in cols. (3) and (4) of Table 5. Percentage variabilities of the estimated means, when villages are sampled with 3 lines of one furlong each, are found to be somewhat greater than that obtained from samples with 3 clusters of 30 plots per village. This will be seen from cols. (5) and (6) of Table 5.

TABLE 5. ESTIMATED PERCENTAGES OF AREA UNDER PADDY CULTIVATED OBTAINED BY (a) CLUSTER SAMPLING AND (b) LINE- SAMPLING WITHIN THIRTY VILLAGES SELECTED AS THE FIRST STAGE UNITS, AS PER SCHEME 1 IN THE GIRIDIH-BENGABAD-GANDE BLOCK (224 SQ. MILES)

visits	period of survey	percentage of land under paddy with error		percentage variation of the block mean	
		mean ± s.e.		cluster	line
		cluster of 30 plots at 3 per village (30 villages)	line of 660 ft. length at 3 per village (30 villages)		
(1)	(2)	(3)	(4)	(5)	(6)
2	early September 1956	26.90±4.01	21.84±4.74	14.90	21.73
3	late September 1956	29.52±4.10	24.21±5.34	13.90	22.07
2+3	September (full) 1956	28.21±4.00	22.07±4.17	14.18	18.38

6.7. The percentage of area under the various utilisations as estimated from the unistage line sample of Scheme 2, has been given in col. (2) of Table 6. The mean percentage of area under paddy has been obtained as 18.09%, which fits in consistently with the progress of sowing in August, as has already been shown earlier in

Table 4. The coefficients of variation with L-shaped line of 1320 ft. as given in col. (3) are found to be slightly lower than the corresponding 'total' c. v. obtained in Schemes 1(a) and 1(b) using clusters of 30 plots and lines of 660'.

TABLE 6. UNISTAGE LINE-SAMPLING WITH 'LINES' OF 1320 FT. AS PER SCHEME 2 IN THE GIRIDIH-BENGABAD-GANDE BLOCK (224 SQ. MILES)

land utilisation	mean (n=59)	coefficient of variation
(1)	(2)	(3)
1. paddy	18.99	140%
2. other cereals	9.86	197%
3. ploughed up	3.78	177%
4. fallow	14.20	154%
5. house-site	1.24	352%

7. SECOND EXPERIMENT ON LAND UTILISATION SURVEY WITH AND WITHOUT CADASTRAL SURVEY MAP

7.1. *Plan and programme.* In order to try out the above methods on a larger scale another experiment was conducted over practically the whole of Hazaribagh district in Bihar during the period 11 November 1956 to 15 January 1957. Leaving out certain hilly and unapproachable forest areas, a total of 4667 sq. miles (approximate) comprised of eighteen Survey of India (SI) "cells" was covered by this scheme. These "cells" represented an area of about 256 sq. miles each bounded by a span of 15 minutes along the longitude lines and of 15 minutes along the latitude lines. Three such cells in a compact formation were assigned to each of six workers constituting a team of investigators. The total period of 70 days was split up into two rounds, first and second of 30 days each, with a recess of 10 days in between.

7.2. In the first round, an investigator was allotted a total of nine sample units to be surveyed. Each sample unit consisted of an L-shaped line-traverse with two arms of length 2 furlongs mutually at right angles. The investigator as in the first experiment was to locate a sample point taking his bearings from a convenient salient point shown on the SI map with which he was equipped, guided by a magnetic compass for finding the direction and counting his steps for measuring the distances traversed. The bearings of the located point was to be carefully noted for subsequent reference. On reaching the sample point and choosing one of the eight directions S, N, N-W, W, S-W, S-E, E, N-E assigned at random, he was to proceed in a straight line through the fields, noting the counts of crop intercepts through which he would traverse, the procedure being the same as was adopted in the first experiment. After enumerating a length corresponding to 2 furlongs he was to turn at right angles either to his right or to his left chosen at random, and traverse a fresh length of 2 furlongs in this new direction.

7.3. In the second round, the investigators were to interchange the cells according to a plan and revisit the original sample points located by workers in the first round and traverse a new line of 4 furlongs in a single straight line, starting from

the same sample point. The direction of the 'line' was to be chosen afresh at random. In addition to this he was to enumerate a cluster of 20 serial plots, the plot containing the sample point being taken as the start. This time he was furnished with the cadastral survey maps, and with its help he was to identify the sample point as located by the first worker from land-marks already noted by him. Obviously, a second location of the point according to the bearings already recorded would take much less time than was originally required by the first worker.

7.4. *Results.* Table 7 gives the estimated percentages under different utilisations based on (a) L-shaped line-units of length 4 furlongs surveyed in the first round, (b_1) : straight armed line-units of length 4 furlongs and (b_2) : clusters of 20 plots surveyed in the second round, along with the coefficients of variation.

TABLE 7. PERCENTAGE OF AREA UNDER DIFFERENT UTILISATIONS ALONG WITH THE COEFFICIENTS OF VARIATION BASED ON THE (1) L-SHAPED LINE-UNITS ENUMERATED IN THE FIRST ROUND AND (2a) : STRAIGHT ARMED LINE-UNITS AND (2b) : CLUSTER UNITS ENUMERATED SIMULTANEOUSLY IN THE SECOND ROUND

[total area : 4667 sq. miles; Hazaribagh, November 1956–January 1957]

utilisations	mean percentage of land utilised ($\bar{x}=72$)			coefficient of variation		
	first round (11.11.56 to 11.12.56)	second round (22.12.56 to 22.1.57)		first round survey	second round survey	
	L-shaped line-unit of 4 furlongs	straight-armed line-unit of 4 furlongs	cluster of 20 CS plots	L-shaped line-unit of 4 furlongs	straight-armed line-unit of 4 furlongs	cluster of 20 CS plots
(1)	(2)	(3)	(4)	(5)	(6)	(7)
paddy	19.56	19.53	22.89	107	102	120
other cereals	3.85	6.79	4.07	236	179	203
ploughed up	3.12	1.69	1.76	212	212	222
fallow	15.28	19.22	14.26	130	126	146
homestead	1.19	0.62	0.68	359	307	325
pulses	3.90	4.31	4.62	200	199	210

7.5. The total number of sample units on which this table is based is less than the full quota, number of units having been rejected on account of their incompleteness in one or other of the two rounds. The agreement between the different sets of estimates shown in cols. (2)–(4) of Table 7 is on the whole satisfactory in spite of large sampling errors owing to the smallness of sample size. It is to be noted that the tendency of a systematic underestimation by the 'line'-units is less pronounced in this experiment than in the earlier one.

7.6. Coefficients of variation given in cols. (5)–(7) of Table 7 suggest that the 'line'-units of both types are nearly equivalent to clusters of 20 plots and that the straight-armed line is somewhat better than the L-shaped one.

7.7. Table 8 gives the coefficient of variation of the proportions of area under different utilisations by sub-units of varying lengths from 1 furlong to 4 furlongs built up successively from the straight-armed full unit of 4 furlongs.

The coefficients of variation are found to fall with an increase in unit size and as expected more sharply in utilisations with low proportion. Least square fits in the form c.v. $= a(x)^{-g}$ where x represents the length of 'line' were units in furlongs, made for each utilisation. The parameters a and g obtained from these fits have been given in cols. (7) and (8). The values of g are quite large which indicates that the intra-class correlation within a 'line'-unit is small and advantage by increasing the length of the 'line'-unit is considerable. Cols. (9)–(12) give the computed size of sample expected to give a margin of error of 5% for an average district when sampled with line-units of varying length from 2 to 8 furlongs. These have been obtained on the basis of the graduated values of c.v. obtained from the least square fits.

TABLE 8. OBSERVED COEFFICIENTS OF VARIATION OF THE PROPORTION OF AREA UNDER DIFFERENT UTILISATIONS AND THE SIZE OF SAMPLE REQUIRED TO ATTAIN A GIVEN PRECISION USING LINE-UNITS OF VARIOUS LENGTHS BASED ON A LINEAR FIT IN THE FORM C (C.V.)$=a(x)^{-g}$

[total area : 4667 sq. miles; Hazaribagh, November 1950–January 1957]

utilisation	proportion of land utilised as estimated from straight-armed line-units of 4 furlongs					least sq. fit, c (c.v.) $=ax^{-g}$		number of line-units of different sizes (x) expected to give a margin of 5% error			
	mean	coefficients of variation by size of sub-units (x)									
		1 fur-long	2 fur-longs	3 fur-longs	4 fur-longs	a	g	2 fur-longs	4 fur-longs	6 fur-longs	8 fur-longs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
paddy	19.53	137	118	108	102	137	0.21	557	416	346	310
other cereals	6.79	234	203	176	170	233	0.21	1616	1197	1011	888
ploughed up	1.69	278	248	220	212	280	0.20	2362	1781	1505	1340
fallow	10.22	100	158	138	126	191	0.30	973	645	502	424
homestead	0.62	730	431	423	307	678	0.44	10040	5476	3844	3003
pulses	4.31	277	216	195	190	271	0.28	1089	1354	1076	912

7.8. It will be seen that for utilisations of very low proportions, the required sample size or the length of a 'unit' is inordinately high. There is a limit, however, to which a 'line'-unit can be increased in length. If the 'line'-unit is made too large, the task of keeping to and describing a straight course becomes extremely difficult. Besides, the tension felt by the investigator in maintaining a correct count of the large number of cumulative steps and the attended risk of making mistakes become great.

7.9. *Cost of enumeration.* During the first round, the investigators enumerated a single type of sample unit, namely, the L-shaped 'line'-units of a total length of 4 furlongs, one at each sample point. Much time had to be spent in locating the sample point with the help of a magnetic compass and counting of the steps traversed. In the second round, the work of location was easier; the investigator was to proceed to the same point already located and identify its position on the village map from

its bearings as noted by the first worker. He had then to enumerate two types of sample units, one straight-armed 'line'-unit of 4 furlongs and one cluster of 20 plots, both starting from the sample point. The additional time entailed in enumerating a cluster of 20 plots must have been appreciably offset by the saving of time in spotting the sample point already located in an earlier round as will appear from cols. (2) and (5) of Table 9 given below.

TABLE 9. COST OF FIELD ENUMERATION IN A UNISTAGE SAMPLING OF LAND UTILISATION WITH AN AREA COVERAGE OF 4667 SQ. MILES
(Hazaribagh, November 1956)

operation	average hours spent in field work					
	first round (one L-unit of 4 furlongs after location of sample point)			second round (straight line unit of 4 furlongs plus one cluster of 20 plots at prelocated sample point)		
	per sample unit	per working day	percent of total (gross) hours engaged	per sample unit	per working day	percent of total (gross) hours engagrd
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. enumeration	4.2*	3.2*	13	5.3**	3.9**	16
2. journey	4.4	3.3	14	5.1	3.8	16
3. balance of 24 hours	23.1	17.1	73	22.3	16.3	68
total	31.7	24.0	100	32.7	24.0	100

* Time spent in reaching the sample point from the chosen salient point and in actual enumeration of the line-unit.

** Actual enumeration of the sample unit (line and cluster).

7.10. The two rounds, in respect of time requirement, do not therefore stand on strictly comparative grounds, and it is difficult to mark out actual costs for the separate operations as sufficiently detailed time-records were not maintained. Nevertheless, one common feature in both the rounds appears to be that 6.5–7.7 hours of effective field work inclusive of journeys were spent per day, about half of which was spent on actual enumeration work. Time spent per sample unit for enumeration was 4.2 hours in the first round including the time taken to traverse the distance from a salient point to the sample point. In the second round, when the sample point was already located and marked the net time spent for enumeration of one 'line'-unit and one cluster of 20 plots worked out to be 5.3 hours.

7.11. The density of sample units in the present experiment was doubtlessly a very thin one. With a greater density of sample units to be surveyed per sq. mile, journey time is expected to be relatively less and more time could be spent on actual enumeration work. It appears, however, that even with about 5 hours of solid enumeration work at the disposal of the investigator per day, the maximum size of 'line'-unit could not be made much larger than 6 furlongs, i.e. three-fourths of a mile. With larger units, the investigator would have to stay on overnight in the same village and continue his work on the same 'line'-unit on the second day also. This would involve camping problems and would lead to an increase in the overhead costs.

8. General observations

8.1. In areas where a plot-wari village map is not available for reference, a sampling unit has to be devised such as will make use of only the actual fields, i.e. patches of land utilisations physically identifiable on the ground. In these experiments, attempt has been made to locate random points in space by traversing approximately given distances along given directions chosen as coordinates where the coverage was one full district of average size. The following experiences have been gained:

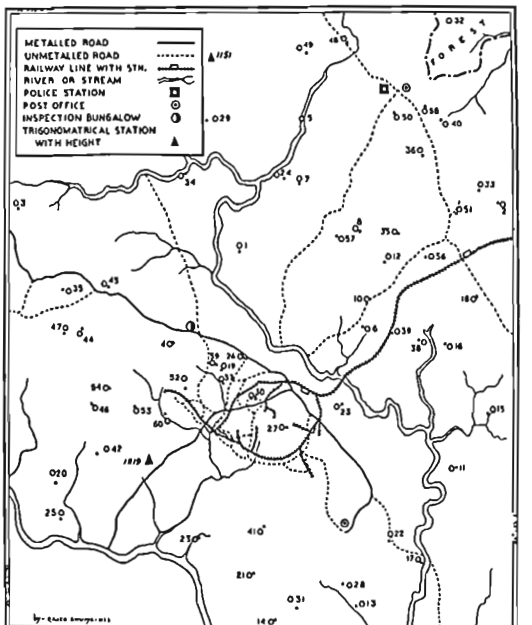
(i) It appears that with some practice it is possible to locate random points on the ground with a reasonable accuracy, guided by the SI maps and aided by a magnetic compass.

(ii) It has been found that 'line'-units can be traversed with the help of a magnetic compass and the 'crop'-intercepts can be enumerated in terms of steps which can be fairly standardized.

(iii) Further investigations seem to be necessary for determining the rules of traversing over steep slopes and wide footpaths especially in terraced area, so that the line traversed may correspond to the cadastral survey measurements.

(iv) In actual operations not making use of large scale maps, the process of location would be extremely laborious and a good deal will depend on the quality of the field investigators. A small group of tried and picked up men could be organised to carry on land utilisation surveys in specially difficult areas where a frame is entirely lacking.

8.2. In the course of these experiments, the need and utility of a system of permanent pillars scanning the entire district systematically in two directions was keenly felt. The country would then be split up into a large number of cells of even size. The location within such cells in the second stage would be very convenient with reference to these corner posts. If the cells would be made very small, a unistage sampling, i.e. picking out a number of such cells at random and completely enumerating them, could be thought of. This is perhaps an wishful dream of the statistician. The idea in concrete terms is something like this. The country representing an area of about 1250,000 sq. miles may be meshed into 4-mile squares. At interval of 4 miles (East-West and North-South) a parallel system of ferro-concrete pillars could be erected on which the coordinates of the bearings x, y would be inscribed, representing x miles due East and y miles due North. The number of such pillars would come up to the order of a lakh for the whole of India. Instead of erecting *ad hoc* structures for each individual purpose, a multipurpose system of such 'national' pillars could be erected once for all accommodating all the communicating channels like telegraph, telephone, power and such others. An ultimate division of these cells into sixteen one-mile squares by erecting sub-pillars every one mile, in a scheme spread over years, could give an ideal frame for area sampling, and cadastral survey maps of regular shapes corresponding to each mile-square could be prepared replacing the old village maps of irregular size and shape, thereby economising printing, paper, and storing space.



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SENGUPTA, J. M. (1950) : Some experiments with different types of area sampling for winter paddy in Giridih, Bihar : 1945. *Sankyā*, 13, Part 3.

Paper written : November, 1959.
Paper received : June, 1964.

Direction of the line... 7 (west). length of line... 1320 ft. = 528 steps

field srl. no.	utilisation	inter-cept in steps	cumulative steps					
			all utilisation	utilisation 1 (paddy)	utilisation 2	utilisation 3	utilisation 4	utilisation 5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Paddy	28	28	28				
2	Paddy	24	52	52				
3	Sargujia	18	70					
4	Fallow	10	80					
5	Paddy	14	94	66				
6	Paddy	9	103	75				
7	Road	6	109					
8	Potato	25	134					
9	Ploughed up	10	144					
10	Paddy	18	162	93				
11	Paddy	6	168	99				
12	Kurthi	90	258					
13	Sargujia	32	290					
14	Fallow	68	358					
15	Ploughed up	44	402					
16	Paddy	10	412	109				
17	Paddy	27	439	136				
18	Paddy	52	491	188				
19	Homestead	20	511					
20	Fallow	17	528					
21		528						
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								

SPECIAL FIELD SURVEY EXPERIMENT, HAZARIBAGH

LAND UTILISATION FORM

Investigator	Sample point (S.U.) No. 6					
Name : SUSHIL KUMAR SINHA	axes of refer-ence	co-ordinates in		salient point to sample point		
Roll : A(3)		0.0 miles (15′ S.I.map)	steps (inv.)	salient point	direction in degrees	distances in steps
Equivalent of step in feet (0.0′)... 2.5	X	5.0	10560	1	355	1858.56
	Y	8.9	18797	2	282	2027.52

description of objects for identification of sample point	sample pt. to object		name and address, if a household
	degr.	steps	
A big tree (mahua) marked			
P.6 × A(3)	270	31	×
A tin shed	216	85	Lilu Shakh, vill—Sarlakhurd, P.S.–Potarbar

Name of owner/possessor of field No. 1/field (×) Radha Mahto

Father's name...Sona Mahto, Vill...Sarlakhurd, P.S. Potarbar.