ABSTRACT OF PAPERS PRESENTED AT THE 16th ANNUAL GENERAL MEETING HELD AT NEW DELHI IN JANUARY 1963

PART I

1. *Unbiased Ratio Estimators. K. V. R. Sastry, Regional Office of the F.A.O. for Asia and the Far East.*

Hartley and snbsequently several authors have considered a linear function r^* of the two conventional biased estimates $\hat{r} = \bar{y}/\bar{x}$ and $\bar{r} = 1/R\ \Sigma\ Y/X$ of ratio $\rho = \bar{Y}/\bar{X}$ which provides an "almost unbiased estimate" of Q in the sense that the bias vanishes to a second order of approximation in terms of what the present author defines as "moment coefficients". Investigation into the efficiency of r^* relative to $\tilde{r}$ by Paswal and some other authors, however, has not been sufficiently explicit for ready reference and particularly that of Paswal appears rather incomplete. A more explicit investigation of efficiency to the fourth order of approximation in moment coefficients has revealed that the estimate r^* is generally more efficient in cases where a ratio estimate is often considered.

In situation where knowledge of population mean $\bar{x}$ is available, an alternate estimate of Q has been proposed in terms of r and $\bar{r}$ and shown to be completely unbiased when the regression of y on x is linear.

2. *Unbiased Ratio Estimate. M. V. Jambunathan, Karnatak University.*

Though ratio estimates are generally biased in certain circumstances, it has been noted that the Ratio method yields unbiased estimates.

Taking the variance of Y in any array proportional to a given function $\phi(x_i)$ of x_i it is shown in this paper the best unbiased linear estimate of R the ratio of y to x in the population is given by the statistic

$$R^1 = \frac{\sum \dfrac{X_i Y_i}{\phi(X_i)}}{\sum \dfrac{X_i^2}{\phi(X_i)}}.$$

Applying this method to cluster sampling where clusters are of unequal size it is seen that $\phi(x_i) = x_i\{1 + (x_i - 1)\rho\}$ where x_i denotes the size of the i-th cluster and the intra-cluster correlation. Taking the mean in the i-th cluster as $\bar{y}_i$ that is $\bar{y}_i = \bar{y}_i/x_i$ the best unbiased estimate of R comes out as

$$R^1 = \frac{\Sigma w_i Y_i}{\Sigma w_i}$$

where

$$w_i = \frac{X_i}{1} + (x_i - 1).$$

This shows that the weighted average of cluster means the weight, being as specified above is the best unbiased linear estimate of Y. It has been shown that this estimate is also the maximum likelihood estimate.

Some other special cases where (a) $\phi(x_i) = 1$, (b) $\phi(x_i) = x_i$ (c) $\phi(x_i) = x_i^2$ have also been considered and the best unbiased linear estimates in this case have been obtained.

3. *An Almost Unbiased Ratio Estimates.* *Ravindra Singh, I.A.R.S., Library Avenue, New Delhi*-12.

A technique of reducing the bias of the ratio estimate has been suggested by Quenniere (1956) in which the sample of size $2n$ is randomly split in the sub-samples of sizes in each. Let Y_{R_1}, Y_{R_2} and Y_{R_3} denote the ratio estimates based on samples of size n, n and $2n$ respectively. Now he considers the weighted ratio estimates

$$Y_R = aY_{R_1} + bY_{R_2} + cY_{R_3}$$

where

$$a + b + c = 1.$$

The weights a, b, c are chosen in such a way so as to reduce the bias to the order of $1/n^2$.

In this paper we have tried to find out the optimum sizes for two sub-samples. A method has been given to find optimum value of r when $(n - r)$ and $(r + n)$ are taken to be the sizes of two sub-samples in place of n. The same weighted ratio estimate has been considered. Ratio estimates Y_{R_1}, Y_{R_2} and Y_{R_3} are now based on samples of sizes $(n - r)$, $(n + r)$ and $2n$ respectively.

4. *A Two-Phase Sampling on Two Occasions with Partial Replacement of Units.* *D. Singh and B. D. Singh, I.A.R.S. (I.C.A.R.), New Delhi*-12.

In this paper, sampling on two occasions has been extended to cover this case of double sampling for stratification with two strata—one of them consisting of units having values zero. The optimum solution for n', the size of the preliminary sample, n, that of sub-sample in non-zero stratum and q the fraction of units replaced on second occasion have been obtained. The behaviour of the efficiency of double sampling for variations of p_1, the size of non-zero stratum and S^2 the square of the coefficient of variation have also been examined separately.

5. *Methods of Estimation in Fertilizer Surveys.* *K. B. L. Rastogi, I.A.R.S., New Delhi.*

Institute of Agricultural Research Statistics is conducting pilot sample surveys of fertilizer and other manuring practice in a few selected districts each year. The main objectives of these surveys are to evolve suitable sampling technique for estimating total consumption, crop-wise consumption and the percentage area benefited by various fertilizers and manures. The sampling plan of these surveys is a stratified two-stage design with Tehsil as a stratum, a village as the primary sampling unit and a cultivator as the secondary and ultimate sampling unit. Villages were selected with probability proportional to the cultivated area and cultivators were selected with probability proportional to the number of survey numbers cultivated by them. For each selected cultivator, the information is collected by enquiring, regarding the various crops grown by him, the quantity of manures applied to each crop and the area benefited by each manure, etc.

Alternative estimates and their relative efficiencies have been investigated with the help of the data collected in the above-mentioned enquiries. Two of the methods of estimation are indicated below:

1. Work out for each selected village in a stratum the sample average of the ratios of the value of the character under study for the particular crop to the selection probability, for each cultivator and then find their weighted average using inverse of the relation probability for the village as weights.

2. Multiply the first estimate by the factor

$$\frac{A\text{, the area under the crop in the stratum } X_1\, n\text{, the No. of villages selected in the stratum}}{\sum_i^n \dfrac{A_i\text{, the area under the crop in the } i\text{-th selected village}}{P_i\text{, the selection probability for the village}}}$$

6. *Size and Cost of Surveys and Observational Errors— A Quantitative Model. Dr. Mrs. V. Mukherjee, Poona.*

The observational error in the observed values in a sample has been treated as a random-variable whose mean and variance are taken to be decreasing functions of the cost per observation. The determination of the sample-size when such observational errors are present has been studied in various situations.

7. *On Mathematical Representation of Gene Action and Interaction. P. Narain, I.A.R.S., New Delhi.*

The problem of describing gene action and interaction in metric characters by using the mathematical expression of genetical laws was attempted by Hayman (1955). His treatment was however restricted to the case of two alleles at each locus whereas a general genetic theory should deal with an arbitrary number of alleles at each locus. In this paper an attempt has been made to extend Hayman's device to the general case of an arbitrary number of alleles at a locus. The case of three alleles at a locus has been considered in detail. Representing the six genotypes possible in this case by a two-dimensional stochastic variable $Q = (u, v)$ a mathematical expression of law of segregation is obtained. The genotypic value of an individual $M(u, v)$ is then represented as a polynomial function of the variables u and v. By working out the variances of individual components, their combinations and covariances between various combinations of the two components u and v the variance of the offspring Q of a cross $Q_a' \times Q_a''$ is obtained. It is shown that this variance reduces to the expression given by Mather (1949) for variance of the family obtained by selfing the heterozygote. Generalisation to the case of a n alleles at a locus is indicated.

8. *On Fleece Classification through Discriminatory Analysis. U. G. Nadkarni, I.A.R.S., New Delhi.*

In classification of fleeces of Magra breed in Rajasthan according to quality attributes the fleeces were required to be visually classified into four groups. Coarse, medium II, medium I, and fine... The four important fleece characters namely fibre diameter, staple length, crimps/in percentage of modullated fibres were studied for each of a number of selection fleeces at the Wool Analysis Laboratory, Bikaner. The technique of discriminatory analysis is utilised to study the reliability of visual grading. Three discriminant functions have been fitted to classify the fleeces into four groups by repeated dichotamy and the probability of misclassification by this method is compared with that due to the classification by the maximum of the likelihood scores L_1, L_2, L_3, L_4 for the four groups.

9. *Method of Solving the Non-linear Programming Problem in Sample Surveys. R. Jagannathan, I.A.R.S., New Delhi*-12.

Often it is desired to obtain information on more than one character. The problems of optimum allocation among strata on stages of sampling become complicated when varieties under study increase from one to two or more.

Since the precision of an estimate is expressed by its variance, an upper limit is set to the variance of the estimate of each character. For any given sampling procedure a cost function may be constructed and restrictions placed on the sample number. The problem of optimum allocation rests in minimising the cost function $c = C_0 + \Sigma C_i m_i$, subject to

$$V_i \leqslant d_j \text{ when } V_j = a_{0j} + \sum_i \frac{a_{ij}}{m_i}$$

are functions of sample numbers. This reduced to a problem of minimising a contex separable function subject to two linear constraints. We solve the problem in two stages. First, we arrive at the local star optimum—vertex of convex set S defined by the constraints at which the value of the function C is as great as the value of function at any other vertex of S. Then by successively minimising suitably defined convex quadratic functions under the same constraints, we get a sequence of approximate selections which converge to the optimum selection.

10. *A Technique of Controlled Selection in Surveys on Fruit Crops. Dr. B. V. Sukhatme and M. S. Avadhani, I.A.R.S., New Delhi.*

In surveys on Fruit Crops the design generally adopted is stratified random sampling with Tehsils or groups of Tehsils as strata. Since the units within a stratum are selected at random it happens frequently that the selected units are scattered all over the stratum and some of them lie even in the interior rendering themselves to be "unapproachable". Due to their non-approachability the field staff may find it difficult to contact the units within the scheduled time and either omit them altogether or supply some data of doubtful reliability. The former will result in non-response which cannot be avoided. In either case the estimate will be biased and the precision of the estimate will be seriously affected. Further, due to the spread of the units over the entire stratum, the travelling cost from unit to unit will considerably increase the cost of the survey. A "Technique of controlled selection" has been suggested for the purpose of obtaining a representative sample so as to minimise the travelling cost and the chances of inclusion of non-approachable units in the sample. An appropriate method of estimation has also been indicated.

11. *Spherical Error Probabilities and the Bias of an Estimate of SPE.*
Naunihal Singh, Delhi.

This paper gives the probability that a point (x, y, z) whose co-ordinates are chosen randomly and independently from the distribution

$$f(x, y, z) = \frac{1}{(2\pi)^{3/2}\ \sigma_x \sigma_y \sigma_z}\ e^{-\frac{1}{2}\{(x/\sigma_x)^2 + (y/\sigma_y)^2 + (z/\sigma_z)^2\}} \qquad (1)$$

will be within a sphere with centre at the origin and redius *i.e.*,

$$P(k, \sigma_x, \sigma_y, \sigma_z) = \underset{\sqrt{x^2+y^2+z^2} < k\sigma_x}{\int\int\int} f(x, y, z)\, dx\, dy\, dz \qquad (2)$$

Also it discusses the bias of $S\hat{P}E_1$ (an estimate of SPE with center at the origin), when actually the center does not coincide with the origin but differs by small magnitudes. In that case the variance of SPE, is given by

$$E(S\hat{P}E_1 - SPE)^2 = C_1^2 [C_2^2 E(\hat{\sigma}_1^2) - 2C_2 E(\hat{\sigma}_1)\sigma + \sigma^2]. \qquad (3)$$

where C_1 and C_2 are constants and is the population value under the hypothesis $\sigma_x = \sigma_y = \sigma_z = \sigma$

and

$$\hat{\sigma}_1^2 = \frac{1}{3n}\sum_1^n (x_i^2 + y_i^2 + z_i^2)$$

$$F \equiv (\hat{\sigma}_1) = \sqrt{\frac{2}{3}}\frac{\sigma}{\sqrt{n}}\, e^{-\lambda} \sum_{m=0}^{\infty} \frac{\lambda^m\, \Gamma\frac{1}{2}(3n + 2m + 1)}{m_1\, \Gamma\frac{1}{2}(3n + 2m)}$$

$$E(\hat{\sigma}_1^2) = \sigma^2 (1 + \lambda)$$

where

$$\lambda = \frac{1}{2\sigma^2}(m_x^2 + m_y^2 + m_z^2)$$

$$E(\theta) = m_\theta.$$

PART II

1. *Mixed Model Analysis of Fertilizer Experiments in Cultivators' Fields. M. N. Ghosh and S. K. Srivastava, I.A.R.S., New Delhi.*

Fertilizer experiments in fields distributed over the country has been conducted during the last few years. The analysis according to the usual mixed model, in which the observed yields are represented as a component due to various effects which are independent random variables is unrealistic in this case because the interaction term is likely to be correlated with main effects. Scheffe's model seems to be better in this case and the analysis of fertilizer trials described in Abraham and Uttamchand (*Journal of the Indian Society of Agricultural Statistics*, 1957) was made on this basis. Mean squares of usual sum of squares was obtained under the new model and the usual test for interactions was found to be unbiased.

2. *Construction of Some Series of Asymmetrical Factorial Designs with Small Number of Replications. P. R. Sreenath and M. N. Das, I.A.R.S., New Delhi.*

Das (1960) has given a method of construction of balanced asymmetrical factorial design $q \times 2^2$ in $2q$ plot blocks through B.I.B. design. As these designs require a large number of replications, the partially balanced asymmetrical factorial designs $q \times 2^2$ in $2q$ plot blocks were introduced. An attempt has been made to further reduce the number of replications. The problem of generalisation of these methods of construction to the case of the designs $q \times 2^n$ in $q \times 2^p$ plot blocks has also been attempted. The results obtained are given below.

(i) The design $q \times 2^2$ in $2q$ plot blocks can be obtained through B.I.B. (or P.B.I.B.) design in b replications where b is the number of blocks in the incomplete block design. In the present paper a method has been discussed through which such designs can be obtained in only $b/2$ replications.

(ii) Designs of the type $q \times 2^2$ in $2q$ plot blocks have been obtained in only two replications, when q is even.

3. *Estimation of Missing Data in a Latin Square.* *Naunihal Singh, Defence Science Laboratory, Delhi.*

The problem of estimating the missing data in a latin square has been considered in this paper. The method of maximum likelihood is employed to arrive at the results. Methods for obtaining unbiased maximum likelihood estimates of the error sum of squares are discussed in order to test two or more treatment differences simultaneously. Variance-Covariance matrix of estimates is given together with a numerical example for illustration.

4. *On Response Surface Designs.* *P. R. Ramachander and M. N. Das, I.A.R.S., New Delhi.*

Several series of response surface designs for fitting second-order surfaces have been obtained. Each of the series gives designs which are of incomplete asymmetrical factorial type as against the rotatable designs which are incomplete symmetrical factorial. Through these designs response at the central region can be estimated with greater precision than that possible through central composite rotatable designs. These designs can be considered rotatable for the levels of certain of the factors when the levels of others are kept fixed.

5. *Power of Tukey's Test for Non-additivity.* *M. N. Ghosh and Diwakar Sharma, I.A.R.S., New Delhi.*

In a two-way classification if x_{ij} is the observation in the i-th row and j-th column $(i = l, \cdots, p, j = q)$ and these are independent normal variables with means μ_{ij} and variance σ^2, we very often consider the model to be an additive one, *i.e.*, if $\mu_{ij} = \mu + \alpha_i + \beta_j$. We consider $C_{ij} = 0$. Tukey (*Biometrics*, 1949) has suggested a test for the hypothesis $C_{ij} = 0$ by considering the ratio of

$$S_1 = \frac{[\Sigma x_{ij} (x_{i\,.} - x_{..}\, x x_{ij} - x_{..})]^2}{\Sigma (xC_{.} - x_{..})^2\, \Sigma (x_{.j} - x_{..})^2}$$

with Error $S.S. - S_1$. Tukey had shown that under the null hypothesis this leads to a F-distribution with d.f. $(l, pq - p - q)$. The power of this test has been considered in this paper and it is shown that under the alternatives of the form $C_{ij} = C\alpha_i\beta_j$. Tukey's test has very good power properties.

6. *On Maximising the Number of Factors in 2^n Factorial Designs and the Fractional Replication Derivable from Them.* G. K. Shukla and M N. Das, I.A.R.S., New Delhi.

Fisher (1940) considered the problem of maximising the number of factors each at two levels that can be accommodated in a given block size without confounding any main effect and two factor interactions. Subsequently Bose (1947) obtained such maximum number when no main effect or the interaction up to three factors is confounded. No exact information regarding the maximum number of factors when no main effect or interaction up to four factors is confounded is available in literature. The particular case has the special interest in that from confounded designs with no interaction with up to four factors is confounded, fractionally replicated designs in which the identity group of interactions does not contain any interaction up to four factors can be obtained and in such fractionally replicated designs no two-factor interaction will be in alias with any other two-factor interactions, allowing thereby the estimation of all two-factor interactions. Hence an attempt has been made to obtain the maximum number of factors that can be accommodated in given block size without confounding any interaction with less than five factors. The results obtained are given below.

Maximum no. of factors	Block size	Fractional possible with the block size
11	2^7	$1/2^4$
17	2^8	$1/2^9$
22	2^9	$1/2^{13}$
28	2^{10}	$1/2^{18}$
38	2^{11}	$1/2^{27}$
51	2^{12}	$1/2^{39}$

While all efforts have been made to ensure correctness the results depend on the assumption that among the number of confounded interactions (independent only) lower orders get confounded in higher number.

7. *Response Surface Designs for Agricultural Experimentation. M. N. Das and B. S. Gill, I.A.R.S., New Delhi.*

The possibilities of applying second-order rotatable designs for agricultural field experimentation has been investigated. The advantages and disadvantages of ordinary confounded factorial designs relative to rotatable designs for studying response surfaces have been discussed. Several rotatable designs in 3 and 4 factors at 3 or 5 levels split into blocks of equal size have been presented. Application of ordinary factorial designs for exploration of response surfaces has also been discussed.

8. *Sampling Studies for Determining Standards in Commercial Grading of Cotton. V. V. R. Murty, I.A.R.S., New Delhi.*

At present Ag-marking of cotton is based on varietal purity of the crop and the system does not take into consideration the fibre properties such as fibre length, fineness and strength which are known to be equally important for judging its quality. The trade use standards worked out by the East Indian Cotton Association which also do not include the fibre properties. In trade, for a commodity like cotton there is a serious risk of adulteration of a superior variety with an inferior one and the mixture passed on to the purchaser as one of superior quality. Ag-marking based on the important fibre properties prevents such malpractices or at least keeps such a risk to the minimum. In order to work out suitable standards needed in Ag-marking of a variety, it is necessary to study the range of variation of each of these properties from samples of cotton drawn from a genuine produce. Such a study should include the seasonal variation in the mean value of a fibre property in order that the results should be of practical utility on a future occasion.

For this purpose the Directorate of Marketing and Inspection had conducted sampling studies on variety No. 2087 in Surat District of former Bombay State during the years 1956–57 to 1959–60 under the technical guidance of I.A.R.S. The samples were analysed for the various technological properties by the Technological Laboratory, Matunga, and the rest results supplied by them were statistically examined at I.A.R.S. About 200 samples were selected during the main baling season, *viz*., February to May of each of the years. In each year the sample was suitably allocated among the months (strata) and also size strata formed by the factories on the basis of the number of bales pressed by them in a previous year. In addition to the test results information was also obtained from the Technological Laboratory in regard to the variation in the mean value of the properties over a larger number of years. These data were suitably utilised to work out an estimate of the true variation in the mean value between years. Similarly, for working out an estimate of the variation between samples within a year the data collected from the investigations had been utilised. With the help of these estimates and the estimated mean value of each property the lower tolerance limit in case of mean fibre length and pressley strength index and upper tolerance limit in case of micronaire value were calculated at 95 per cent. probability level. Such limits were calculated separately for different sizes of samples to be drawn on the future occasion. Frequency curves and the goodness of their fit was tested for each of the properties and in each year similar tolerance limits were also worked out from the data of grader's evaluation reports received for the investigation during 1959–60 indicating class, colour, etc., of each sample.

9. *Application of Component Analysis Techniques in the Study of Pest and Disease Survey Data. T. P. Abraham and R. K. Khosla, I.A.R.S., New Delhi.*

In the survey on incidences of pests and diseases, usually a large number of variables are involved as different pests and diseases affect a given field. Further, periodical observations have to be taken on the same pest or disease. For a statistical study of the data, it is very useful to have the number of variables reduced. The technique of component analysis which is often used in econometric and psychometric investigations can be tried for this purpose. In the present study, the data of pest and disease incidence collected in 103 fields taken on a random sample basis in Cuttack District in Orissa were examined using the component analysis techniques. Incidences of stem-borer, Gall fly, Helminthosporium and Blast, which were the major pests and diseases, were taken for the study. The index calculated by component analysis technique was found to account for about 40 per cent. of the overall variation. The regression of yield on index showed no significant association between the two. In general, the incidences were low which may be one of the reasons for the lack of association between yield and the incidence. A system of scoring each field by taking the simple average of the ranking of the field based on the incidence of individual pests and diseases showed that such scores are highly correlated with the first component derived from the component analysis. Therefore, it appears that this simple system of scoring can be used in place of the more complicated and laborious component analysis technique. Association of the index with agronomic and soil factors is being studied. The studies are also extended to more data.

10. *A Comparative Study of Fertilizer Models with Bivariate Nutrients*• *T. A. Ramasubban, I.A.R.I., New Delhi.*

The present study attempts to investigate the economic characteristics of a few of the statistical models which define the relationship between the physical output of wheat crop and the two variable inputs of fertilizers in the form of (N_2) and Phosphoric Acid (P_2O_5) nutrients. The need and logic for studies of the type envisaged here have been emphasised, notably by Prof. Earl O. Heady.

The data used in this study relate to an experiment conducted at the Agricultural Research Farm, Halvad, Jamnagar District, Gujarat State, to investigate the fertiliser response of N_2 and P_2O_5 nutrients on irrigated wheat. The data relate to two consecutive years 1955–56 and 1956–57 and have been used by Desai and Doshi (1962) to fit a Cobb-Douglas function of the type

$$Y_1 = b_0^{(1)}\, x_1^{b_1^{(1)}} . x_2^{b_2^{(1)}} \qquad (1)$$

to determine the economic optima of fertilisation and yield. In an attempt to study the efficiency of (1), we have here fitted, for the same data, the following models:

$$Y_2 = b_0^{(2)} + b_1^{(2)} x_1 + b_2^{(2)} x_2 + b_{11}^{(2)} x_1^2 + b_{22}^{(2)} x_2^2 + b_{12}^{(2)} x_1 x_2 \qquad (2)$$

$$Y_4 = b_0^{(3)} + b_1^{(3)} x_1 + b_2^{(3)} x_2 + b_{11}^{(3)} \sqrt{x_1} + b_{22}^{(3)} \sqrt{x_2} + b_{12}^{(3)} \sqrt{x_1 x_2} \qquad (3)$$

where Y is the yield of wheat in lb./acre, x_1 is the level of N_2 per acre and x_2 the level of P_2O_5 per acre, x_i $(i = 1, 2)$ is related to the corresponding actual input x_i (expressed in lb./acre) through the relation $x_i = (x_i + 20)/20$.

Variance analyses have been carried out to determine the significance of b's as well as the adequacy of 'fit' (2) and (3). For each model, the values of the multiple correlation coefficient (R) have been evaluated for every additional regression constant fitted, in order to see the improvement in the degree of fit. In brief, the results show that $R = 0{\cdot}8319$, $0{\cdot}9080$ and $0{\cdot}9218$ for equations (1), (2) and (3) respectively.

Having ascertained the statistical superiority of functions (2) and (3) over the Cobb-Douglas type, we embarked on their economic comparison. Towards this end, iso-product maps and lines of constant price-inclines have been drawn for models (2) and (3). On account of the difficult nature of these functions, resort to geometrical methods have been made in order to facilitate the drawing of these diagrams. The optimum resource-combinations of the fertilisers for different levels of output are worked out by the method of successive approximations. Tentative conclusions, adopting this approach, show, for example, that for a yield of 1,000 lb./acre the amount of optimum N_2/P_2O_5 combinations are 22·25/5·75, 13·80/7·80 and No. 75/5·31 for models (1), (2) and (3) respectively. With prices of Sulphate of Ammonia at Re. 0·792 per lb. of N_2 and of Single Superphosphate at Re. 0·652 per lb. of P_2O_5 the optimum costs incurred by the farmer to reap the above yield, are: Rs. 21·37 for equation (1), Rs. 16·02 for (2) and Rs. 11·98 for (3). Thus, on economic grounds too, models (2) and (3) score over (1), in that in order to obtain the same yield, lesser fertilizer- combinations are predicted, which in turn reduce the farmer's expenditure on these resource-inputs.

11. *Some Methodological Considerations to Determine Changes in Cropping Pattern. T. A. Ramasubban, I.A.R.I., New Delhi.*

Before initiating an analysis of the factors favouring changes in one or more cropping patterns pertaining to time period or region it is necessary, as a first step, to establish the existence of such changes, their sizes and directions. This paper attempts to do this. A closer inquiry into the methodology of measuring the changes in the cropping patterns shows that two types of changes inherent in them can be identified. The first one, which we call 'shifts' between two or more cropping patterns relates to the inter-variations in the overall distributions of the patterns, resulting from physical displacements of the crops. Such displacements are brought about by an increase or decrease in the acreage-magnitudes of the crops constituting the patterns. The other type of change which we refer to as 'deviations' between the patterns comes about as a consequence of the differences in the extent of intra-variations in the array of cropped acreages within the individual cropping patterns. These variations are termed as 'intraspersions'. In the existing literature, these two changes are not differentiated and the measure adopted to indicate the change is one of percentages which is not very refined and cannot lead to valid conclusions.

In this paper, we have paid separate attention to these two changes and have shown that their behaviour need not necessarily be in unison with one another. We then proceed to suggest reliable measures, which will assess the nature and extent of these changes and will also provide statistical validity for such assessments.

To determine 'shifts' as defined here, we have employed the ranking methods and rank correlation coefficients; and to measure 'deviations, which are dependent on the 'intraspersions' of the cropping patterns' we have proposed two indices that are related to the coefficient of variation.

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