Vol XXIV
No. 1

ISSN 0019-5014

JANUARY-
MARCH
1969

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

NOTES

ADOPTION PROCESS AND CHANGE INDUCING CAPACITIES OF CHARACTERISTICS*

RESEARCH PROBLEM

In most of the adoption studies pertaining to agricultural practices, the major goal is identification and isolation of individual socio-economic and other characteristics which are significantly associated with adoption of either a single farm practice or an index of adoption. The general approach to achieve this consists of first grouping the farmers under two categories, namely, non-adopters and adopters,[1] and then to make efforts to understand the consistency with which the characteristics differentiate between these two categories. The dichotomous categorization of farmers, however, overlooks the commonly accepted concept of stages in adoption process.[2] This is because under the non-adopter category are grouped not only those farmers who are totally ignorant of the innovation but also those who are at such different stages of adoption as awareness, interest, evaluation and trial. It is felt that the failure to take into consideration the differences between the stages reached by 'non-adopter' category farmers greatly limits the understanding about the real effectiveness of different characteristics in the adoption process.

A measure of effectiveness of a characteristic could be its capacity to induce change in farmers' behaviour. Operationally, this could mean, how far forward the characteristic can take farmers in adoption process. The underlying assumption here is that each characteristic has a distinct change inducing capacity and

---

* G. L. Verma and K. N. Raju have done most of the tabulation and statistical calculations.

1. Some of the studies following this approach are: Bryce Ryan and Neal C. Gross, "The Diffusion of Hybrid Corn in Two Iowa Communities," *Rural Sociology*, Vol. 8, March, 1943, pp. 15-24; Neal Gross, "The Differential Characteristics of Accepters and Non-Accepters of an Approved Agricultural Technological Practice," *Rural Sociology*, Vol. 14, June, 1949, pp. 148-156; Neal Gross and Marvin J. Taves, "Characteristics Associated with Acceptance of Recommended Farm Practices," *Rural Sociology*, Vol. 17, December, 1952, pp. 321-327; C. Paul Marsh and A. Lee Coleman, "The Relation of Farmer Characteristics to the Adoption of Recommended Farm Practices," *Rural Sociology*, Vol. 20, December, 1955, pp. 289-296; Santi Priya Bose, "Characteristics of Farmers who Adopt Agricultural Practices in Indian Villages," *Rural Sociology*, Vol. 26, June, 1961, pp. 138-145. In the most recent study on the subject in India a measure of 'innovativeness of adoption,' covering ten agricultural practices has been used. In this study, however, the researchers have considered, instead of adoption, the stage of trialas the best measure of adoptive innovativeness. The reason provided by them is that, "the distribution of the scores clearly indicated that the 'trial' curve had a more normal distribution than 'adoption'." See Prodipto Roy, Frederick C. Fliegel, Joseph E. Kivlin and Lalit K. Sen : Agricultural Innovation Among Indian Farmers, National Institute of Community Development, Hyderabad, 1968, p. 24. (This is one of the research reports of the larger project, "Diffusion of Innovation in Rural Societies" directed by Everett M. Rogers of the Department of Communication, Michigan State University, under contract with U.S. Agency for International Development. The project was conducted in Brazil, Nigeria and India).

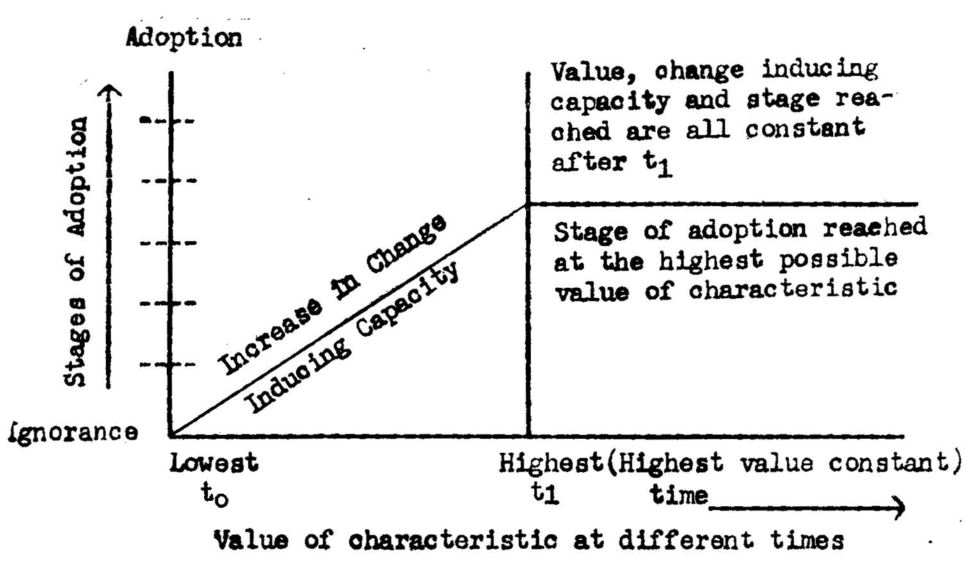
2. George M. Beal, Everett M. Rogers and Joe M. Bohlen, "Validity of the Concept of States in the Adoption Process," *Rural Sociology*, Vol. 22, June, 1957, pp. 166-168; Eugene A. Wilkening: Acceptance of Improved Farm Practices in Three Coastal Plains Counties, North Carolina AES Tech. Bull., 98 Raleigh, 1952, p. 16; Herbert F. Lionberger: Adoption of New Ideas and Practices, Iowa State University Press, Iowa, 1960, pp. 21-32; Everett M. Rogers: Diffusion of Innovations, New York, Free Press, 1962, pp. 76-120; Rex R. Campbell, "A Suggested Paradigm of the Individual Adoption Process," *Rural Sociology*, Vol. 31, December, 1966, pp. 458-466; Y. P. Singh and Udai Pareek, "A Paradigm of Sequential Adoption," *Indian Educational Review*, Vol. 3, January, 1968, pp. 1-26.

that the capacity varies from characteristic to characteristic.[3] According to this assumption, while the characteristic having high change inducing capacity would take the ignorant farmers right up to the adoption stage, those not having such high capacity would take them only up to a certain stage and no further in the adoption process. It is also possible that the capacity could be limited to inducing change only between certain stages. Hence, to understand the relative effectiveness of characteristics, it would be necessary to know, in each case, the 'distance' between the starting stage (from which the characteristic begins to be effective) and the end stage (up to which it is effective, *i.e.*, it can take the farmers). Under dichotomous categorization such information is not available, since here all the stages up to the trial stage (any one of which could be a starting stage) are grouped together under 'non-adopter' category. As such this approach fails to provide a proper understanding of the relative effectiveness of different characteristics in adoption process.

If a characteristic is significantly associated with adoption, it could, in general, be assumed to have some inherent power or capacity to influence the behaviour of farmers. Under dichotomous categorization of farmers, characteristics significantly associated with adoption would differentiate between the two categories, *viz.*, adopters and non-adopters. (That is, according to our assumption it has capacity to take the group of farmers considered under non-adopter category to adoption stage). However, if instead of these dichotomous categories, the different stages which the non-adopter farmers have reached are considered, then, it will be erroneous to assume that such a characteristic would also consistently

---

3. It could be further assumed that capacity to induce change is directly and positively related with the value of characteristics; it is lowest when the value of characteristics in the lowest and reaches maximum when the characteristic reaches its maximum possible value. Once the maximum change inducing capacity is reached, it remains constant and as such, after this point in time, is independent of time dimension. Whatever stage in adoption process is reached by the farmer when the characteristic has generated its maximum change inducing capacity, also remains constant after this point. Diagramatically this could be shown thus :



differentiate between the adopters and farmers at different stages. This means that even if a characteristic differentiates between adopters and non-adopters, for the same population it may or may not differentiate between the adopters and those, say, at heard stage, or say, at trial stage. Since under the influence of a characteristic having high change inducing capacity ignorant farmers become aware of the innovation, go for trial and ultimately adopt it, such a characteristic should differentiate between (1) presence and absence of awareness, (2) mere awareness and awareness followed by trial, and (3) mere trial and trial followed by adoption. If a characteristic fails to differentiate between the adopters and farmers, say, at a particular stage, then it could be considered to lack the power to induce change at that particular stage. The extent of association of a characteristic with adoption and with different stages in the adoption process, such as awareness and trial would indicate the relative change inducing capacity of that characteristic between different stages. Similarly, a comparison of extent of association of different characteristics would indicate relative change inducing capacity of these characteristics.

With these assumptions, in this paper an attempt is made to find out the relative change inducing capacities of four characteristics with a view to understanding whether the characteristics are effective throughout the adoption process or are effective only at certain stages in the adoption process.

METHOD

The four selected characteristics are tested for significance of association by using Chi-square test. To measure the extent of association mean-square contingency ϕ^2 is used; where $\phi^2 = \frac{X^2}{N}$, X^2 being the Chi-square value and N being the number of respondents.[4]

Contingency tables for Chi-square test are prepared as follows : Assuming the frequency distribution of respondents at not-heard, heard, trial and adoption stages to be A, B, C, D and A_1, B_1, C_1, D_1, respectively, according to low and high category of a characteristic, then under dichotomous categorization of respondents as non-adopters and adopters, the cell frequencies would be $\frac{A + B + C \mid D}{A_1 + B_1 + C_1 \mid D_1}$ .... (1). To find out whether the characteristic differentiates between those at different stages of adoption and adopters the cell frequencies would be, $\frac{A \mid D}{A_1 \mid D_1}$....(2). $\frac{B \mid D}{B_1 \mid D_1}$......(3), and $\frac{C \mid D}{C_1 \mid D_1}$..(4). To find out whether the characteristic differentiates between those who are not aware of the innovation and those who are aware of it, the cell frequencies would be $\frac{A \mid B + C + D}{A_1 \mid B_1 + C_1 + D_1}$ .... (5). Similarly, to see whether the characteristic differentiates between those who have the awareness but have not

4. G. Udny Yule and M. G. Kendall: An Introduction to the Theory of Statistics, 14th Edition, Hafner Publishing Company, New York, 1950, pp. 52-53.

tried the innovation and those who have tried it, the cell frequencies would be as $\frac{B \mid C + D}{B_1 \mid C_1 + D_1}$ .... (6). In (5), under heard or awareness category (second column in the cell) C and D are also considered in addition to B, the reason being that those at higher stages of trial and adoption have to be aware of the innovation. Similarly, in (6), under trial category (second column in the cell), in addition to those who are at trial stage, those at adoption stage are also considered, since it is assumed the latter must have gone through the trial stage before arriving at the adoption stage.

SAMPLE

Data used in this paper come from the nation-wide survey on "Awareness of Community Development in Village India," carried out by the National Institute of Community Development in 1965. The survey covered 365 villages scattered all over the country, chosen by modified probability sampling procedure.[5] A total of 7,224 adults (1,414 leaders and 5,810 other villagers) were covered by the survey. For the present paper a sub-sample of 135 villages was drawn. From each village out of the total sixteen non-leader respondents, four were selected at random. In all 540 informants in 135 villages composed the present sample.

SELECTION OF CHARACTERISTICS

The four characteristics considered here cover three major areas, namely, economic, social and communication. The economic characteristic considered here is the farm size or size of land holding. Under social are considered, education and extra-village contact (urban contact), and under the communication characteristic is considered contact with change agent. In Indian situation all the four characteristics have consistently been shown to be related positively and highly with adoption behaviour.[6] The innovation considered is adoption of improved variety of seed. Stages of adoption considered here are 'Heard' (Awareness), 'Trial,' and 'Adoption.'

ANALYSIS

The percentage distribution of respondents at different stages of adoption according to size of land holding, level of education, degree of contact with change agent and degree of urban contact is given in Table I.

---

5. For details about the sampling design see Lalit K. Sen and Prodipto Roy: Awareness of Community Development in Village India, National Institute of Community Development, Hyderabad, 1966, pp. 8-12; or Lalit K. Sen, V. R. Gaikwad, G. L. Verma: Peoples Image of Community Development and Panchayati Raj, National Institute of Community Development, Hyderabad, 1967, pp. 1-3.

6. According to Roy and others, all the four variables considered here are highly associated with trial index of agricultural practices in India: The correlation between farm size and trial index was $r = 0.24$, between education and trial index $r = 0.36$, between urban contact and trial index $r = 0.30$, and between change agent contact and trial index $r=0.49$, *op. cit.*, pp. 32, 46 and 64.

TABLE I—PERCENTAGE DISTRIBUTION OF RESPONDENTS AT DIFFERENT STAGES OF ADOPTION ACCORDING TO LOW AND HIGH CATEGORIES OF LAND HOLDING, EDUCATION, CONTACT WITH CHANGE AGENT AND URBAN CONTACT

Variable		Stages of adoption				
		Not-heard	Heard	Trial	Adoption	Total
1. Land holding	Low	83.4(151)	80.6 (79)	85.6 (89)	65.6(103)	78.2(422)
	High	16.6 (30)	19.4 (19)	14.4 (15)	34.4 (54)	21.8(118)
		(181)	(98)	(104)	(157)	(540)
2. Education	Low	84.0(152)	69.4 (68)	68.3 (71)	59.9 (94)	71.3(385)
	High	16.0 (29)	30.6 (30)	31.7 (33)	40.1 (63)	28.7(155)
		(181)	(98)	(104)	(157)	(540)
3. Contact with change agent	Low	82.3(149)	54.1 (53)	41.3 (43)	35.7 (56)	55.7(301)
	High	17.7 (32)	45.9 (45)	58.7 (61)	64.3(101)	44.3(239)
		(181)	(98)	(104)	(157)	(540)
4. Urban contact	Low	43.1 (78)	20.4 (20)	17.3 (18)	15.3 (24)	25.9 (140)
	High	56.9(103)	79.6 (78)	82.7 (86)	84.7(133)	74.1 (400)
		(181)	(98)	(104)	(157)	(540)

Note : Figures in parentheses are actual frequencies.

Table II gives the results of Chi-square test of significance for association between adoption stages and selected variables, and also the extent of association where association is found to be significant.

TABLE II—RESULTS OF CHI-SQUARE TEST OF SIGNIFICANCE FOR ASSOCIATION BETWEEN ADOPTION STAGES AND SELECTED VARIABLES, AND EXTENT OF ASSOCIATION

Variable	Dependent variable categories*					
	Non-adopter—Adopter N=540	Not-heard—Adopter N=338	Heard—Adopter N=255	Trial—Adopter N=261	Not-heard—Heard N=540	Heard—Trial N=359
	(1)	(2)	(3)	(4)	(5)	(6)
1. Land holding	SS (0.0378)	SS (0.0422)	SS (0.026)	SS (0.0492)	S (0.0082)	—
2. Education	SS (0.0264)	SS (0.0729)	—	—	SS (0.0396)	—
3. Contact with change agent	SS (0.0673)	SS (0.2268)	S (0.0187)	—	SS (0.144)	SS (0.0212)
4. Urban contact	SS (0.0244)	SS (0.0912)	—	—	SS (0.0773)	—

Note : Figures in parentheses are ϕ^2 value.

SS and S indicate that values are significant at 1 and 5 per cent level respectively, d.f. 1 in all cases.

*In col. (3) 'Heard' means those *at* heard stage; in col. (4) 'Trial' means those *at* trial stage; in col. (5) 'Heard' includes all those who are aware of innovation; in col. (6) 'Heard' means those *at* heard stage, while 'Trial' includes adopters also.

From Table II following observations could be made:

(1) Each of the four characteristics differentiates between adopters and non-adopters (col. 1).

(2) Comparison of adopters with those at different stages (col. 2, 3 and 4), shows that at 1 per cent level of significance, land holding differentiates in all the three cases, while the remaining three characteristics differentiate only in one case, *i.e.*, between not-heard and adoption. Contact with change agent, however, also discriminates between heard and adoption but only at 5 per cent level of significance.

(3) It could be seen (col. 5, 6 and 4) that, except land holding all the characteristics differentiate between awareness and absence of it at 1 per cent level of significance. Land holding also differentiates between these categories but only at 5 per cent level of significance. Contact with change agent is the only characteristic that differentiates between awareness and awareness followed by trial, and land holding is the only one that differentiates between trial and adoption.

Patterns of association that emerge from the examination of the values of ϕ^2 indicating the extent of association are shown in Diagram 1.

Considering the ϕ^2 values, from Table II and Diagram 1 following observations could be made :

(1) The values of ϕ^2 indicating extent of association are in general of a very low order.[7]

(2) Under dichotomous categorization of respondents as non-adopters and adopters (col. 1) the maximum association is found in case of variable contact with change agent, followed by land holding, and minimum association in case of urban contact.

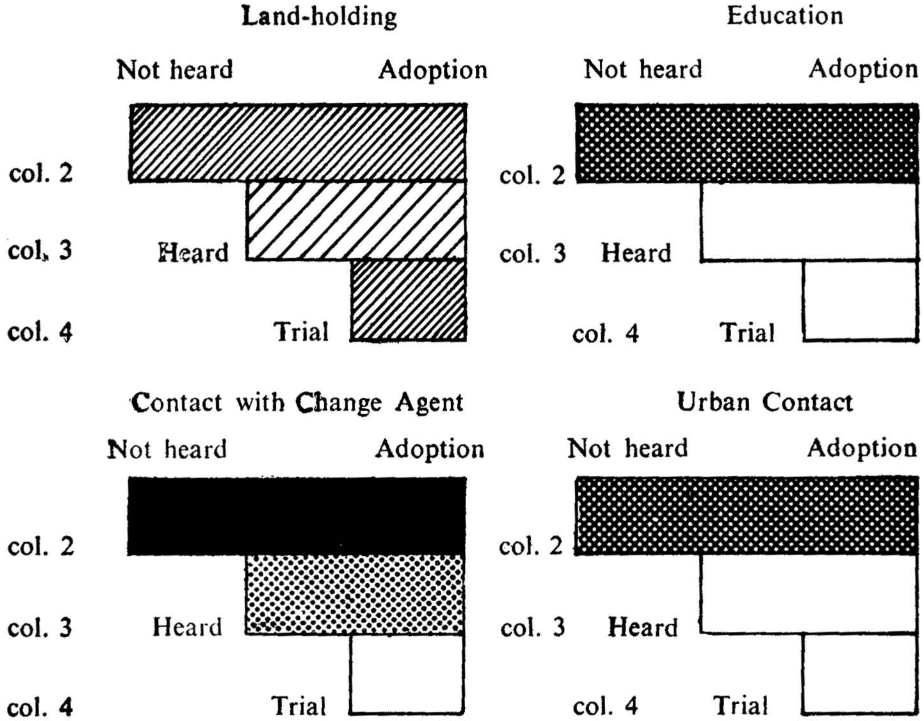
(3) When the categories are not-heard and adopter (col. 2), the extent of association is the highest for contact with change agent. However, when the categories are heard and adopter (col. 3), then for this characteristic the extent of association comes down to a very low level, indicating that the main association must be between the section not-heard and heard of the adoption process. When the categories cover trial to adoption section (col. 4), it could be seen that there is no association, again indicating that whatever extent of association was found, when the categories cover heard to adoption section, must be concentrated between heard to trial section. These assumptions seem to be correct as could be seen from the values of ϕ^2 obtained when the whole process is broken as shown in col. 5, col. 6 and col. 4. Similar observations could be made in the case of other characteristics.

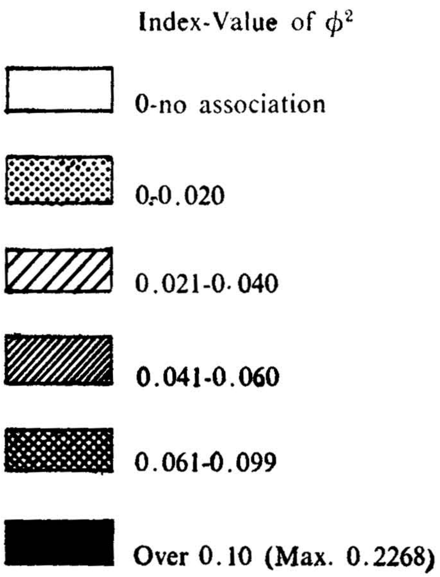
From the above discussion the following pattern of association emerges (Diagram 2).

7. The value of ϕ^2 is 0 when there is absolutely no relationship between two variables. In case of 2 x 2 tables it has an upper limit of unity when the relationship between the two variables is perfect. See Hubert M. Blalock: Social Statistics, McGraw-Hill, 1960, 0.229.

Diagram 1

EXTENT OF ASSOCIATION OF SELECTED VARIABLES WITH ADOPTION STAGES

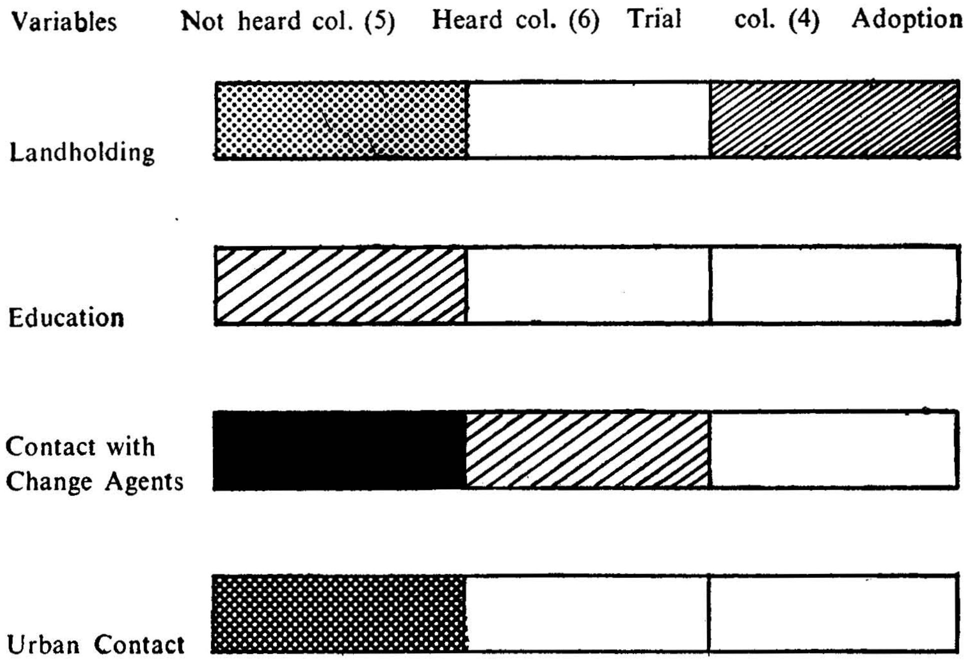


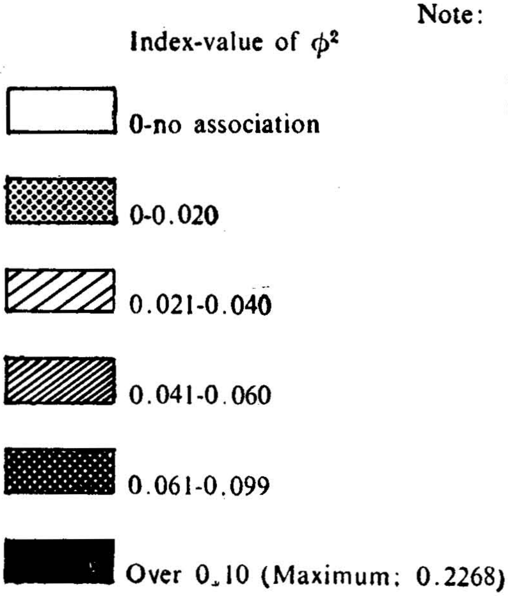


Note : In col. (3) 'Heard' means those *at* heard stage; in col. (4) 'Trial' means those *at* trial stage.

Diagram 2

PATTERN OF ASSOCIATION OF SELECTED VARIABLES WITH STAGES OF ADOPTION





Note: In col. (5) 'Heard' includes all those who are aware of innovation; in col. (6) 'Heard' means those *at* heard stage, while 'Trial' includes adopters also; in col. (4) 'Trial' means those *at* trial stage.

From Diagram 2, judging from the relative strength of association with awareness of innovation it could be said that contact with change agent is the most highly and significantly associated characteristic, followed by urban contact, education and land holding in the order given. Again, except contact with change agent, no other characteristic is significantly associated with trial. And when categories are mere trial and trial followed by adoption, except land holding, no other characteristic is significantly associated with adoption.

CONCLUSIONS

All the four selected characteristics differentiate between adopters and non-adopters. All these also differentiate between ignorants (not-heard category) and adopters. However, when the process of adoption is considered as consisting of stages, then it is found that each characteristic differentiates differently and to different extent. This indicates that while all the four characteristics are capable of moving farmers forward in the adoption process, the change inducing power of these characteristics is not only different but also is concentrated at different sections in the process. Contact with change agent can mainly move the farmers from the stage of ignorance to the stage of knowledge and to some extent can move them to trial and innovation. However, it does not seem to be very effective in moving farmers from trial stage to adoption stage. Large land holding seem to be the most effective factor to move farmers from trial stage to adoption stage. It also seems to have some power, though of a very low strength, that could help farmers in becoming knowledgeable. It, however, lacks power to move a person having knowledge of the innovation to try it. Urban contact and education seem to be effective only at the initial stage of the process where these impart knowledge and do not seem to be of any significant value to reach the farmers to higher stages in adoption process.[8]

V. R. GAIKWAD,
G. L. VERMA
AND
K. N. RAJU*

8. *Authors' Note:* Just when the final typing of this paper was over we came across C. H. Shah's review of Agricultural Innovations in Indian Villages and of two other allied reports by Roy and others, in *Indian Journal of Agricultural Economics*, Vol. XXIII, No. 3, July-September, 1968, pp. 77-78. In our paper we have more or less used the line of investigation suggested by Shah. Also, our findings in general support some of his hypotheses. According to him, "For fuller study it would be considered necessary to investigate the influences at all the three stages. This would have enabled us to isolate the influences that operate at different stages. One would expect social factors, organizations, contacts, communications to dominate the acquisition of knowledge or undertaking trials of improved practices. As against this at the stage of actual adoption of improved practices, economic factors, education, etc., would dominate more than other factors. It is at the level of actual adoption we can argue that the profitability of inducing change would be more carefully considered by the farmer."

*Deputy Director (Sociology), Senior Research Assistant and Junior Research Assistant respectively, National Institute of Community Development, Rajendranagar, Hyderabad, Andhra Pradesh.

CHARACTERISTICS OF FARM INNOVATIONS ASSOCIATED WITH THE RATE OF ADOPTION

Introduction

The rapid scientific development of new ideas, practices, and products since the beginning of the twentieth century has generated considerable research dealing with the process of how people adopt new ideas. A large number of studies concerned with diffusion and adoption of farm innovations has been made in recent years in North America. Most have focused on the personal, social, economic, and cultural factors affecting the rate of adoption. But the characteristics[1] of farm innovations, which may be major determinants of the rate of adoption, have not been thoroughly explored by the research workers. This study is, therefore, an attempt to examine whether selected characteristics of farm innovations as perceived by farm operators have any relationship to the rate of adoption. The two major purposes of the present study are : (*i*) to develop a comprehensive set of characteristics by which a wide variety of farm innovations may be compared ; and (*ii*) to find the association between the characteristics of farm innovations and their rates of adoption to determine whether the innovations which are adopted at the same rate possess similar characteristics.

Related Studies

Some diffusion studies have shown that the characteristics of farm innovations are closely associated with the rate of adoption.[2] Rogers listed five such characteristics of farm innovations : (*i*) relative advantage, (*ii*) compatibility, (*iii*) complexity, (*iv*) divisibility, and (*v*) communicability.

Brandner and Kearl, in their study of hybrid sorghum adoption, reported that the persons who evaluated an innovation as congruent with previous favourably evaluated practices accepted the innovation more rapidly than those who failed to make such an evaluation.[3] The congruency factor was stronger than age, education, income, and the economic importance of the innovation considered.

Griliches[4] reported that in the long run and when the United States of America was taken as a whole, many of the sociological variables either did not vary enough to be significant or tended to cancel themselves out, leaving the economic variables as the major determinants of the patterns of technological changes. Farmers in the corn belt accepted hybrid at a faster rate than the farmers in the South, because the absolute magnitude of profit was higher in the corn belt than

---

* This paper is based on the thesis submitted for the degree of Master of Science in the Department of Extension Education, University of Guelph, Ontario, Canada. Grateful acknowledgements are made to Prof. G. L. Warlow, Dr. Helen C. Abell, Dr. J. Singh, and Dr. James D. Tarver for their guidance and constructive criticisms. The author is also grateful to Dr. N. S. Shetty for giving valuable comments on an earlier draft of the paper.

1. The characteristics used in the present investigation are : initial cost, divisibility for trial, complexity, operating cost, mechanical attraction, rate of cost recovery, financial return, communicability, compatibility, and saving of labour.
2. Everett M. Rogers : Diffusion of Innovations, Free Press, New York, 1965, pp. 121-147.
3. L. E. Brandner and B. Kearl, "Evaluation for Congruence as a Factor in the Adoption Rate of Innovations," *Rural Sociology*, Vol. 29, No. 3, September, 1964, pp. 288-303.
4. Z. Griliches, "Hybrid Corn : An Exploration in the Economics of Technical Change," *Science*, CXXXII, 1957, pp. 275-280.

in the South. According to Yeh and Heady,[5] the farm innovations were not extensively used or accepted, unless they were found to be profitable. Bose[6] reported that relative advantages of the innovation are significantly related to its rate of adoption.

It is obvious that a controversy exists between the relative importance of economic and sociological variables in explaining the rate of adoption of innovations. Economists have maintained that the rate of adoption could be explained by such economic variables as profitability, while sociologists have stated that the rate of adoption could be explained by sociological variables, such as congruency.

Brandner and Straus[7] compared congruence and profitability in the diffusion of hybrid sorghum in the two areas of Kansas, corn growing and non-corn growing. They reported that congruency was a basic element in the diffusion process and had a greater relative importance than profitability. Wilkening[8] found that the rates of adoption of farm innovations are related to (*i*) communicability of the innovation, (*ii*) the immediacy of the return from the adoption, and (*iii*) the seriousness of the need the innovations meet.

A study was conducted by Kivlin[9] in Pennsylvania to determine the relationship between the characteristics of farm innovations and their rates of adoption. He found that those farm practices rated low in complexity and high in compatibility and saving of time, were adopted more rapidly than others. Those practices, which rated high in mechanical attraction and saving of physical discomfort, also tended to be adopted rapidly, but the correlations were not statistically significant. He was able to explain only 51 per cent of the variation on the basis of 11 different attributes.

Petrini[10] reported that those innovations which implied changes in farm management or expansion of the farm were slower in being adopted than innovations which meant improvements in production or labour techniques. The latter innovations were adopted twice as fast as the former ones. He also reported that innovations which were demonstrated had a more rapid rate of adoption than others. In regression analysis, 71 per cent of the variation in the rate of adoption was explained by two main variables, *viz.*, the economic importance of the innovations according to the farmers' perceptions and the perceived complexity of the innovation. Economic as well as social variables were found to be essential in explaining the rate of adoption.

On the basis of the literature cited above, some characteristics of farm innovations were developed to determine the relationship between these characteristics and their adoption rates.

5. M. H. Yeh and E. O. Heady, "Why Do We Use New Practices," *Iowa Farm Science*, Vol. XIV, 1960, pp. 14-16.
6. S. P. Bose, "The Diffusion of a Farm Practice in Indian Villages," *Rural Sociology*, Vol. 29, No. 1, March, 1964, pp. 53-56.
7. L. E. Brandner and M. Straus, "Congruence Versus Profitability in the Diffuson of Hybrid Sorghum," *Rural Sociology*, Vol. 24, No. 4, December, 1959, pp. 381-382.
8. E. A. Wilkening: Acceptance of Improved Farm Practices in Three Coastal Plain Counties, Agricultural Experiment Station Technical Bulletin 225, Chapel Hill, North Carolina, U.S.A., 1952.
9. J. E. Kivlin : Characteristics of Farm Practices Associated with the Rate of Adoption, Unpublished Ph.D. dissertation, Pennsylvania State University, University Park, 1960.
10. F. Petrini : The Rate of Adoption of Selected Agricultural Innovations, Report of the Agricultural College of Sweden, Uppsala, Sweden, 1966, pp. 57-61.

Statement Of Hypotheses

Characteristics of farm innovations, as perceived by corn growers, are related to the rate of adoption in the following manner :

(*a*) The higher the initial cost, the lower will be its adoption rate.

(*b*) The more difficult it is to try an innovation on small scale, the less it is adopted.

(*c*) The more complex the practice is, the less it is adopted.

(*d*) The higher the operating cost of an innovation, the lower will be its adoption rate.

(*e*) The more mechanical attraction an innovation has, the more readily it is adopted.

(*f*) The quicker the rate of cost recovery of an innovation, the higher will be its adoption rate.

(*g*) The larger the financial return of an innovation, the more readily it will be adopted.

(*h*) The more communicable an innovation is, the quicker it will be adopted.

(*i*) The more an innovation differs from the farmer's past experience, the lower will be its adoption rate.

(*j*) The more labour an innovation saves, the more readily it will be adopted.

Methodology

Brant County, an important corn growing area in Ontario, was selected for the present investigation. It is situated in Southern Ontario in a zone of 2700 to 2900 heat units available for corn production. The soil is suitable for high yields of corn. A list of corn growers was obtained from the office of the Agricultural Representative of the County. Pre-tested questionnaires were mailed to 590 corn growers of Brant County. Out of 590, 255 respondents returned the questionnaires.[11] Seventy-eight questionnaires were not considered because the respondents shifted from corn growing to raising of other crops, such as tobacco. Forty-seven questionnaires were discarded owing to incomplete information. Only 130 responses were utilized in the analysis of data.

New corn practices were selected in consultation with Agricultural Representative and Corn Specialists. Each respondent was asked to indicate which of the 22 selected practices he was currently using and when he started to use them. Since the years of rapid adoption were from 1960 to 1965, it was possible to calculate the cumulative percentage of farmers adopting these practices. Then, the average rate of adoption was determined.[12] The rate of adoption varied from 0.7 to 12.7

11. The percentage of response was low because corn growers found it difficult to rate the characteristics of farm innovations.

12. Kivlin's method was used to compute the rate of adoption of farm innovations. See J. E. Kivlin : *op. cit.*

TABLE I—RATE OF ADOPTION AND MEAN RATING OF THE CHARACTERISTICS OF 22 FARM INNOVATIONS

Farm innovations	Rate of adoption*	Characteristics**									
		1	2	3	4	5	6	7	8	9	10
1. Use a corn planter with modern fertilizer attachment	12.7	1.3	0.9	0.5	0.9	1.1	1.3	1.4	0.4	0.9	1.1
2. Use early maturing hybrids	11.7	0.6	0.3	0.3	0.5	0.6	1.4	1.4	0.5	1.0	0.5
3. Use a corn picker	11.3	1.4	0.9	0.5	1.3	1.2	1.0	1.1	0.4	0.8	1.1
4. Store cob corn in cribs	10.4	0.6	0.4	0.2	0.5	0.5	1.1	1.1	0.3	0.6	0.4
5. Fertilize according to the soil test ..	10.3	1.2	0.6	0.4	1.0	0.7	1.6	1.7	0.6	1.3	0.8
6. Plant corn by May 15	10.0	0.6	0.4	0.3	0.6	0.7	1.4	1.5	0.5	1.1	0.5
7. Treat seed with chemicals to prevent injury by soil insects	9.7	0.4	0.3	0.2	0.3	0.3	1.2	1.2	0.4	0.9	0.5
8. Aim for thick plant population of 1800 per acre	9.4	0.8	0.5	0.4	0.7	0.7	1.3	1.4	1.5	1.1	0.5
9. Harvest silage corn at full dent stage ..	8.6	0.4	0.6	0.3	0.7	0.8	1.2	1.4	0.5	0.9	0.6
10. Use atrazine for weed control and limited cultivation	8.3	1.7	0.9	0.8	1.3	1.1	1.4	1.6	0.6	1.2	1.1
11. Spring plough and use minimum tillage before planting	8.3	0.4	0.4	0.4	0.5	0.9	1.0	1.1	0.4	0.9	1.1
12. Apply extra nitrogen when corn follows corn stalks	8.0	1.1	0.5	0.4	0.8	0.7	1.1	1.2	0.4	0.9	0.4
13. Plough down the major part of fertilizer such as potash	6.6	1.0	0.6	0.4	0.8	0.9	1.3	1.4	0.4	1.2	0.9

(Contd.)

TABLE I—(*Concld.*)

Farm innovations	Rate of adoption*	Characteristics**									
		1	2	3	4	5	6	7	8	9	10
14. Use no extra nitrogen when corn follows a legume sod	5.1	0.2	0.2	0.2	0.2	0.4	0.7	0.7	0.3	0.5	0.6
15. Side dress the major part of fertilizer such as anhydrous ammonia	4.7	1.5	0.8	0.6	1.2	1.0	1.3	1.3	0.6	1.3	0.9
16. Use atrazine for weed control and no cultivation	4.4	1.8	0.8	0.7	1.2	1.1	1.3	1.4	0.6	1.4	1.5
17. Use a combine	2.8	1.9	1.3	0.9	1.6	1.4	0.5	0.7	0.6	1.3	1.3
18. Use a grain dryer	2.3	1.5	1.2	0.8	1.4	1.0	0.6	0.7	0.6	1.1	0.8
19. Use dry shelled corn storage	2.0	1.1	0.8	0.5	0.8	0.8	0.8	0.9	0.4	1.0	0.9
20. Use a picker-sheller	1.3	1.6	1.3	0.8	1.4	1.2	0.6	0.8	0.7	1.2	1.3
21. Use high moisture corn and corn cob meal or high moisture shelled corn	1.1	1.0	1.0	0.7	0.9	0.9	0.8	0.8	0.6	1.1	1.0
22. Use a narrow row width such as 28″ or 30″ or 32″	0.7	1.5	1.3	0.7	1.3	0.7	0.8	1.0	0.6	1.2	0.4

*Average per cent of total adopting per year for the seven years of most rapid growth from before 1960 to 1965.

**Characteristics : (1) Initial cost ; (2) Divisibility for trial ; (3) Complexity ; (4) Operating cost ; (5) Mechanical attraction ; (6) Rate of cost recovery ; (7) Financial return ; (8) Communicability ; (9) Compatibility ; (10) Saving of labour.

The respondents also rated the new corn practices for each of the ten characteristics on a four-point ranking scale. The scale for each characteristic varied from one extreme to the other; for example, initial cost, one of the characteristics of new corn practices, had "low" at one extreme and "high" at the other. The four points of the scale were coded from 0 to 3. The mean rating for each characteristic of the 22 corn practices was determined. A simple correlation analysis was then used to determine the relationship between the characteristics of farm innovations and the rate of adoption. Multiple regression analysis was also used to explain the total variability in the rate of adoption due to these characteristics of farm innovation.

Findings

Table II shows the correlations between the characteristics of farm innovations, as perceived by corn growers, and their rates of adoption.

TABLE II—RELATIONSHIP BETWEEN THE CHARACTERISTICS OF FARM INNOVATIONS AND THE RATE OF ADOPTION*

Characteristics	Correlations between characteristics and adoption rate (r with 21 d.f.)
Initial cost	—.42
Divisibility for trial	.64
Complexity	—.65
Operating cost	—.47
Mechanical attraction	—.30
Rate of cost recovery	.74
Financial return	.68
Communicability	.52
Compatibility	.38
Saving of labour	—.30

* In this sample, a correlation of .41 is significant at the .05 level and a correlation of .53 at the .01 level.

The rate of cost recovery and financial return were highly correlated with the rates of adoption. Farm innovations with quick rate of cost recovery and high financial returns were adopted much more rapidly than those with slow rate of cost recovery and low financial returns. Complexity, initial cost, and operating cost were negatively associated with the rate of adoption. Farm innovations which were more divisible for trial on small scale had more rapid rates of adoption than others. Communicability and compatibility of farm innovations were also correlated with the rate of adoption. However, the correlation between compatibility and the rate of adoption was not statistically significant.

TABLE III—INTER-CORRELATIONS AMONG 10 CHARACTERISTICS OF FARM INNOVATIONS*

Characteristics	Initial cost	Divisibility for trial	Complexity	Operating cost	Mechanical attraction	Rate of cost recovery	Financial return	Communicability	Compatibility	Saving of labour
Initial cost	—	—.85	.87	.96	.81	—.22	—.08	—.75	—.70	.67
Divisibility for trial		—	—.92	—.91	—.77	5.5	.42	.76	.53	—.57
Complexity			—	.92	.81	—.47	—.34	—.86	—.65	.68
Operating cost				—	.85	—.32	—.17	—.83	—.67	.63
Mechanical attraction					—	—.23	—.15	—.65	—.50	.84
Rate of cost recovery						—	.97	.18	—.14	—.23
Financial return							—	.07	—.26	—.15
Communicability								—	.82	—.51
Compatibility									—	—.44
Saving of labour										—

* In this sample, a correlation of .41 is significant at the .05 level and a correlation of .53 at the .01 level.

Saving of labour and mechanical attraction were not significantly associated with the rate of adoption. These characteristics display an association in which the direction was contrary to the expectation. The negative association of these characteristics might be explained in terms of high inter-correlation with the initial cost. Although certain farm innovations were mechanically attractive and saved labour, they were not readily accepted due to the high initial cost.

Table III reveals the inter-relationships of ten characteristics of farm innovations as rated by the respondents. The general observation is that most of the characteristics of farm innovations were significantly correlated. Out of 45 correlations, 28 were significant at the 1 per cent level and 4 were significant at the 5 per cent level.

The initial cost, operating cost, divisibility for trial, complexity, mechanical attraction, communicability, compatibility, and saving of labour were significantly associated with each other. None of these characteristics seemed to be independent. The initial cost, complexity, operating cost, and mechanical attraction were negatively correlated with financial return and the rate of cost recovery, while divisibility was positively correlated with these two characteristics. The inter-correlations indicated that the practices with a high initial cost tended to have high operating cost, high mechanical attraction, and high complexity, along with low financial return and low rates of cost recovery. The correlations of financial return and the rate of cost recovery with communicability, compatibility, and saving of labour were very low, which means that these characteristics were independent of financial return and the rate of cost recovery.

The multiple regression coefficient explained 87 per cent of the variability in the rate of adoption. Petrini[13] reported that 71 per cent of the variation in the rate of adoption might be explained by the two main variables, *viz.*, the economic importance of innovations according to the farmers' perceptions and the perceived complexity of the innovations.

Summary and Conclusions

The findings of this investigation support the conclusion that selected characteristics of farm innovations are useful in understanding adoption behaviour. Since farmers' perceptions of the characteristics of farm innovations and the adoption rates are highly correlated, the following two approaches may increase the rate of adoption : (*i*) direct change in perceptions of farmers of a given farm innovation by educational, motivational, and other means ; (*ii*) modifications in the characteristics of an innovation so as to bring a change in how it is perceived.

RAM NARAIN SINGH†

13. Petrini, *op. cit.*, pp. 57-61.

† Graduate Teaching Assistant in the Department of Sociology and Anthropology, University of Georgia, Athens, Georgia.

DETERMINATION OF EFFICIENT FARMERS : A DISCRIMINANT ANALYSIS APPROACH*

Introduction

In this paper the classification of a set of farmers into efficient and inefficient farmers has been attempted on the basis of a number of efficiency norms and with the help of discriminant analysis. The issue of determination of efficient farmers arises in the context of formulation of a price policy for agricultural commodities, which has to take into account, *inter alia,* the cost of production of crops. A question that has been often raised is : whose costs are relevant for the determination of cost of production? Depending upon the objective of the price policy, the cost of production can be reckoned at a level which covers all farmers or a bulk of them or an average farmer or only an average efficient farmer. While in the short run and in periods of extreme shortages the cost of production of either all or bulk of the farmers may be more relevant, in the long run efficiency alone should be rewarded. Efficiency is by definition a relative concept. Again economic efficiency has to be distinguished from technological efficiency. While measurement of technological efficiency is based on the interdependence of factors of production, economic efficiency takes into account the relationship between output and different inputs and their prices. The determination of efficient farmers in this paper is attempted only on the basis of measures of economic efficiency.

Price Policy and Cost of Production

The need for a price policy for agricultural commodities is being increasingly felt due to constant efforts at planned development of agriculture. One of the guiding principles in formulating a price policy is cost of production for different agricultural commodities. The cost of production data available in the country do not directly meet the needs of the policy-makers. Most of the studies so far made were not specifically designed to collect data on cost of production of different crops with a view to meeting the requirements of formulating a price policy at the national and State levels.

In order that the estimates of cost of production can be utilized for formulating a price policy, it is necessary to have a knowledge of different components of cost. This would facilitate the inclusion of only certain relevant items for the purpose of arriving at a cost estimate that would meet the requirements of a price policy. A basic issue that might arise in the formulation of a price policy on the basis of cost of production could be the question of which costs and whose costs. Different views have been expressed on the concept of cost for framing a price policy. At one extreme it is suggested that the total cost, paid out as well as imputed (*i.e.*, cost 'C' of the farm management studies) should be considered, while at the other the suggestion is that only 'paid out cost' should be taken into consideration. The concept of paid out cost is relevant for formulation in the short run, while the total cost concept is valid for long run.

Probably the most important question that arises is : what is the class of farmers whose cost of production should be considered as the basis for the price

* The views expressed in this paper are the personal views of the author.

formulation ? Three types of cost estimates have been suggested as relevant : (*i*) the average cost of all farmers, (*ii*) the average cost of the efficient farmers, and (*iii*) a bulk-line cost.

The concept of average cost of all farmers has relevance for price determination only if the inter-farm variance is not too large. If the variance is very large, the statistical significance of the average is lost. This is the case with the available farm management data as can be seen from some data given below.

State	Year	Crop	Range of cost per maund (Rs.)
Andhra Pradesh	1958-59	Irrigated paddy	5—21
Maharashtra	1956-57	Irrigated jowar	4—42
	1956-57	Irrigated wheat	9—61
	1956-57	Bajra un-irrigated	5—70
West Bengal	1954-57	Jute	5—49

The concept of average cost of only the efficient farmers has found support on the ground that the objective of price policy should be to reward efficiency. However, in actual practice, problems arise in defining the concept of efficiency of the farmer. Efficiency can be measured by a number of norms. An efficient farmer can be defined as one who produces a unit of output at low cost. But the farmer who produces only small output per unit of input at a low cost cannot obviously be called an efficient farmer. This leads to another concept of efficiency, *viz.*, maximum yield per unit of input. But, just as minimum cost with minimum yield of output, say, per acre, cannot be considered as efficiency, higher yield accompanied by higher cost of production cannot also be termed as efficiency. Further, the question of efficiency of a particular activity on the farm is related to all the activities on the farm as a whole. If efficiency is to be measured with reference to only one of the above criteria, a different set of farmers would emerge with each efficiency measure.

The limitation of the third type of cost, *viz.*, bulk-line cost, is that the bulk-line as related to production might not cover the bulk of area under the crop or the number of holdings.

To meet the problems arising out of the second type of cost and to classify a set of farmers into two categories, *viz.*, efficient and inefficient on the basis of a combination of efficiency criteria, a statistical technique is employed, which is discussed below.

Methodology

Suppose we wish to assign several individuals, on the basis of a measured variate X, to one or other of two populations A and B which differ in their means but whose distributions may overlap. If the mean of A is greater than the mean of B, we would naturally assign an individual with a high value of X to population A and one with a low X to population B. In practice, we often have several variates $X_1, X_2, \ldots\ldots\ldots\ldots X_p$ which may be used for discrimination, and the problem then arises of choosing the best function of these variates for discriminating with the least error, between population A and B. A function of this kind is called a discriminant function. A fixed value Z is estimated on the basis of the discriminant function and individuals with a value of the function greater than Z will be classified as A and those with a smaller value as B.

The variates considered for determining efficient farmers in this paper are the three efficiency criteria, namely, yield of paddy per acre, cost of production of paddy per maund (cost C), and the ratio of value of output to cost. While the first two criteria relate to a particular enterprise, *viz.*, paddy, the output-cost ratio is that of the farm as a whole. This implies that efficiency of a particular enterprise is measured in relation to farming as a whole.

Data and Results

The data are obtained from the "Studies in the Economics of Farm Management, Andhra Pradesh—1958-59" and relate to 93 farmers who had grown irrigated paddy in the first season. The data on the different efficiency criteria for all the 93 farmers have been collected. Looking into all these efficiency criteria, it is difficult to classify each farmer either as efficient or inefficient. The discriminant analysis technique helps in arriving at such a classification. This technique initially requires two clearly demarcated groups of farmers, one which can be termed as certainly efficient and the other as certainly inefficient. Out of the 93 farmers, 14 certainly efficient and 12 certainly inefficient farmers are selected in the following manner.

The average yield per acre and the average cost per maund for all the 93 farmers are calculated. The farmers whose per acre yield is above the average and whose cost per maund is below the average are first identified. Of these, whoever has the output-cost ratio more than unity is considered to be an efficient farmer. While doing this, only those farmers having an operated area of above one acre under paddy have been considered. On the basis of these criteria, 14 farmers out of the 93 could be classified as efficient. Similarly, those farmers who have a yield below the average, cost above the average, output-cost ratio below unity and with area operated more than one acre under paddy are considered to be inefficient farmers. Their number came to 12. Thus of the 93 farmers one group containing 14 efficient farmers and another of 12 inefficient farmers are formed. Between these two groups, there is a well-defined distance so far each efficiency criteria is concerned. A similar distance between the two groups measured by a combination of these criteria is obtained by fitting a discriminant function to the data of these two sets of farmers

The results are given below :

	Average yield per acre (maunds)	Average cost per maund (Rs.)	Average ratio of value of output to cost
Efficient group	32.6	8.4	1.4
Inefficient group	19.1	16.7	0.8

The discriminant function obtained is

$$Z=0.0026X_1-0.0069X_2+0.0636X_3$$

Where X_1 is yield per acre,

X_2 is cost per maund,

X_3 is ratio of value of output to cost.

A quantity analogous to the multiple correlation coefficient can be calculated as

$$R^2=\frac{(b_1d_1+b_2d_2+b_3d_3)\ N_1N_2}{N_1+N_2}$$

where

b_1, b_2 and b_3 are the coefficients in the discriminant function, and

d_1, d_2 and d_3 are the differences in the averages of the two groups.

Then,

$$F=\frac{(N-P-1)\ R^2}{P(1-R^2)}$$ has Snedecor's F with P, N—P—1 degrees of freedom.

R^2 for the above function comes to 0.84 and F value to 44 which is highly significant. Thus the function can be considered as one that can discriminate successfully between the two groups.

The value of Z at the average levels of X_1, X_2 and X_3 works out at 0.0489. If the Z value, after substituting for X_1, X_2 and X_3 for an individual farmer, exceeds the average Z value of 0.0489, he is considered to be an efficient farmer and if the value is less he is taken to be an inefficient farmer.

For each of the 93 farmers, the Z value has been calculated and it is found that 49 farmers have a value more than the average Z value. Thus 49 out of the 93 farmers may be considered as efficient, the remaining can be termed as inefficient.[1] Of the three efficiency criteria, it is found that cost per maund carried maximum weight (43 per cent) followed by the ratio of value of output to cost (31 per cent) and yield per acre (26 per cent).

This technique can be further extended by including some more efficiency criteria like return to investment, return to man-day of labour, etc.

It may be of interest to know the distributions of the efficient and inefficient farmers obtained as above if classified according to the levels of efficiency measured by each of the three efficiency criteria. These frequency distributions are given in Tables I, II and III.

1. Though it is possible to calculate error estimate associated with the Z value for each farmer, the computational procedures are very complicated. Our classification, therefore, suffers from some kind of limitation since the statistical test of significance of differences between Z values for efficient and inefficient farmers has not been applied.

TABLE I—EFFICIENCY MEASURE 1 : YIELD PER ACRE

Level of yield (maunds)	Efficient farmers		Inefficient farmers	
	No.	Per cent	No.	Per cent
Up to 10	—	—	2	4.5
10—20	5	10.2	12	27.3
20—30	16	32.7	24	54.6
30—40	25	51.0	6	13.6
Above 40	3	6.1	—	—
Total	49	100.0	44	100.0

TABLE II—EFFICIENCY MEASURE 2 : COST PER MAUND

Level of cost per maund (Rs.)	Efficient farmers		Inefficient farmers	
	No.	Per cent	No.	Per cent
Up to 5	1	2.0	—	—
5—10	26	53.1	5	11.4
10—15	22	44.9	17	38.6
15—20	—	—	17	38.6
Above 20	—	—	5	11.4
Total	49	100.0	44	100.0

TABLE III—EFFICIENCY MEASURE 3 : RATIO OF VALUE OF OUTPUT TO COST

Level of output-cost ratio	Efficient farmers		Inefficient farmers	
	No.	Per cent	No.	Per cent
Up to 0.4	—	—	1	2.3
0.4—0.8	1	2.0	15	34.0
0.8—1.2	22	45.0	22	50.0
1.2—1.6	18	36.7	5	11.4
Above 1.6	8	16.3	1	2.3
Total	49	100.0	44	100.0

In the above three sets of frequency distributions it may be seen that though both the efficient and inefficient farmers are distributed in all the class intervals, majority of the efficient farmers is found in the higher levels of yield per acre and output-cost ratio and lower levels of cost of production as compared to the distributions of inefficient farmers.

The distribution of these two categories of farmers according to the size of land under paddy is also given below.

Size (acres)	Efficient farmers		Inefficient farmers	
	No.	Per cent	No.	Per cent
Up to 1	8	16.3	11	25.0
1—2	9	18.4	11	25.0
2—5	16	32.6	11	25.0
5—10	7	14.3	8	18.2
Above 10	9	18.4	3	6.8
Total	49	100.0	44	100.0

It can be seen from the above table that efficient farmers are well distributed over all the size classes but inefficient farmers are concentrated in the lower size classes. This shows that efficiency cannot be measured by size of holding alone.

D. RADHAKRISHNA†

FARM SUPPLY RESPONSE—A CASE STUDY OF SUGARCANE IN ANDHRA PRADESH*

The object of this paper is to examine the acreage and output response of sugarcane in Andhra Pradesh to changes in its relative price. It is useful to distinguish between the response of aggregate agricultural output, and the response of output or acreage of a single crop. This paper deals with the latter problem. In recent years, considerable attention has been devoted to the allocative function of prices in production decisions.[1] Here again, a distinction should be made between farmers' allocation of land, and non-land resources, in response to price changes. This study primarily focuses attention on the allocation of 'land' resource.

† Assistant Director, Agricultural Prices Commission, New Delhi.

* This paper was prepared at the Institute of Economic Growth, Delhi. The author is grateful to Dr. C. H. Hanumantha Rao for his valuable guidance and suggestions in the preparation of this paper. He is also grateful to Dr. Raj Krishna for incisive comments on an earlier draft of the paper.

1. Raj Krishna, "Farm Supply Response in India-Pakistan," *Economic Journal*, Vol. LXXII, No. 291, September, 1963, and "Some Production Functions for the Punjab," *Indian Journal of Agricultural Economics*, Vol. XIX, Nos. 3 & 4, July-December, 1964 ; S. C. Gupta and A. Majid: Producers' Response to Changes in Prices and Marketing Policies, Bombay, 1965; D. Ramesh: "A Dynamic Model Analysis of Foodgrain Production and Prices," and "Long and Short-run Elasticities of Acreage under Crops," *Agricultural Situation in India*, Vol. XIX, No. 4, July, 1964 and Vol. XX, No. 5, August, 1965, respectively; Dharm Narain : The Impact of Price Movements on Areas under Selected Crops in India, 1900-39, Cambridge University Press, London, 1965; S. M. Hussain : "A Note on Farmers' Response to Price in East Pakistan," *The Pakistan Development Review*, Vol. IV, No. 1, Spring, 1964. Also see contributions by several participants in the Conference Number of the *Indian Journal of Agricultural Economics*, Vol. XX, No. 1, January-March, 1965.

That changes in relative prices have a significant effect in reallocating resources among agricultural commodities has been demonstrated by observation and empirical evidence concerning sugar in Uttar Pradesh, cotton in Punjab, and jute in West Bengal. This paper attempts to test the same hypothesis, *viz.*, whether there is any significant positive association between changes in relative acreage and output on the one hand and relative prices on the other. It must be readily admitted, however, that for studying acreage response the most appropriate independent variable would be relative profitabilities. In the absence of any information on this aspect, relative prices, and later relative gross income per acre, were used as approximately determining relative profitabilities.

Before presenting the results, reference must also be made to the efficacy of employing lagged relative price in determining the acreage allocation. Apparently, this is based on the assumption that the farmers' expectations regarding current year's relative price are influenced by the previous year's direction of change in relative price. An attempt was also made in this study to examine whether last year's direction of change in the price of sugarcane relative to the price of its competing crop, is a good predictor of this year's direction of change.

Cropping Pattern of the Sugarcane Region in Andhra Pradesh

In the year 1964-65, Andhra Pradesh had 5.7 per cent of the sugarcane acreage of the Indian Union, and 9.6 per cent of the rice acreage. This State ranks fourth and sixth respectively among the sugarcane and rice growing States in India. Among the principal crops cultivated in the State, rice ranks first and sugarcane has the eighteenth place. Sugarcane is one of the important commercial crops in the State, which is mainly confined to the districts of Srikakulam, Visakhapatnam, East Godavari, West Godavari, Krishna, Chittoor, Nizamabad and Medak, which account for 92.5 per cent of the total area under sugarcane. The region comprising these districts also accounts for nearly 56 per cent of the rice acreage in the State, so that, by and large, rice has been the major crop competing for acreage with sugarcane. Nearly 92 per cent of the total rice acreage, and 97.5 per cent of sugarcane acreage, were irrigated during the year 1964-65.

Data

The main sources of data are : Area, Production and Yield Statistics, Growth Rates in Agriculture, Agricultural Prices in India—all published by the Directorate of Economics & Statistics, Ministry of Food and Agriculture, Government of India. For the more recent years, Season and Crop Reports of the Andhra Pradesh Government have been consulted. The study covers a period of 13 years, 1952-53 to 1964-65.

Results

Area, output and yield of sugarcane were regressed against its relative price, yield, and the results, together with other related regressions, are indicated in Table I.

Analysis

Equation I reveals that relative acreage of sugarcane is responding to relative price, although R^2 is not very high. But the regression coefficient is significant

TABLE I

Serial no. of the equation	Period of study and number of observations	Equation	R^2
I	1952-53 to 1964-65 (12 observations)	$\frac{A^1t}{A^2t} = 41.98 + \underset{(0.274)}{0.612^*} \frac{P^1t-1}{P^2t-1}$	0.33
II	1953-54 to 1964-65 (11 observations)	$\frac{A^1t}{A^2t} = 74.24 + \underset{\substack{(0.300)\\ \text{N.S.}}}{0.535} \frac{P^1t-1}{P^2t-1} - \underset{\substack{(0.34)\\ \text{N.S.}}}{0.204} \frac{P^1t-2}{P^2t-2}$	0.30
III	1952-53 to 1964-65 (12 observations)	$\frac{A^1t}{A^2t} = -12.57 + \underset{(0.247)}{0.513\dagger} \frac{P^1t-1}{P^2t-1} + \underset{(0.316)}{0.622\dagger} \frac{A^1t-1}{A^2t-1}$	0.53
IV	1952-53 to 1964-65 (12 observations)	$\frac{O^1t}{O^2t} = 80.72 + \underset{(0.28)}{0.429\dagger} \frac{P^1t-1}{P^2t-1}$	0.20
V	1952-53 to 1964-65 (12 observations)	$\frac{Y^1t}{Y^2t} = 86.50 - \underset{\substack{(0.126)\\ \text{N.S.}}}{0.116} \frac{P^1t-1}{P^2t-1}$	0.08
VI	1952-53 to 1964-65 (12 observations)	$\frac{A^1t}{A^2t} = -31.38 + \underset{(0.27)}{0.595^*} \frac{P^1t-1}{P^2t-1} + \underset{(0.64)}{0.79\ddagger} \frac{Y^1t-1}{Y^2t-1}$	0.43
VII	1952-53 to 1964-65 (12 observations)	$\frac{A^1t}{A^2t} = -7.68 + \underset{(0.21)}{0.53^*} \frac{I^1t-1}{I^2t-1} + \underset{(0.29)}{0.58\ddagger} \frac{A^1t-1}{A^2t-1}$	0.59
VIII	1952-53 to 1964-65 (12 observations)	$\frac{O^1t}{O^2t} = 23.95 + \underset{\substack{(0.66)\\ \text{N.S.}}}{0.827} \frac{Y^1t}{Y^2t}$	0.12
IX	1952-53 to 1964-65 (12 observations)	$\frac{O^1t}{O^2t} = 11.71 + \underset{(0.134)}{0.824^*} \frac{A^1t}{A^2t}$	0.78
X	1952-53 to 1964-65 (12 observations)	$\frac{P^1t}{P^2t} = 172.6 + \underset{(0.213)}{0.407\dagger} \frac{P^1t-1}{P^2t-1} - \underset{(0.210)}{0.96^*} \frac{P^1t-2}{P^2t-2}$	0.74

Note :

$\frac{A^1}{A^2}$, $\frac{P^1}{P^2}$, $\frac{O^1}{O^2}$, $\frac{Y^1}{Y^2}$, indicate, respectively, area, price, output and yield of sugarcane, relatively to its competing crop, rice.

$\frac{I^1}{I^2}$ indicates the aggregate gross relative income per acre of sugarcane.

Subscripts t, t−1, etc., refer to the time period.

* indicates that the coefficient is significant at 1 per cent level.

‡ indicates that the coefficient is significant at 5 per cent level.

† indicates that coefficient is significant at 10 per cent level.

N.S. indicates that the coefficient is not significant.

at 1 per cent level. One explanation for the low R^2 may be as follows. In six out of seven major sugarcane growing districts of Andhra Pradesh, sugarcane is a two-year crop. The figure of 'area under sugarcane' for a particular year includes 'area newly planted' in that year plus carry-over of last year, *i.e.*, area under 'ratoon.' Obviously, for studying farm supply response it is more appropriate to consider only 'area newly planted.' Unfortunately, figures for 'ratoon' and 'newly planted area' are not readily available separately. Hence inclusion of ratoon in the 'area under sugarcane' introduces a certain element of inflexibility into the model. This perhaps explains the low acreage response obtained in the equation.

It is felt that since the current year's acreage includes previous year's ratoon as well, this part of the acreage should respond to price lagged two years. Another equation has been tried with price lagged one year and price lagged two years as the independent variables (equation II). Despite the inclusion of another independent variable, this equation does not seem to explain acreage response better; in fact, R^2 of this equation is lower than that of equation I. This is because in the second equation, the number of observations decline by one. It is clear that ratoon problem cannot be satisfactorily tackled unless we have data indicating every year, which *particular* area is newly planted, along with the *particular* area under ratoon.

In equation III lagged *relative* acreage has been included as another explanatory variable, on the reasoning that this year's relative acreage may depend, to some extent, on the last year's relative acreage. The explanation improves to 0.53. This positive correlation between the relative acreages of the current year and the preceding year may indicate that the farmers are not able to readjust their acreage allocations completely in response to the changes in relative prices within a short period of one year.

Relative output, as shown by equation IV, is responding positively, but to a lesser degree, R^2 being only 0.20. Equation V reveals that relative yield does not seem to be influenced by changes in relative price. This is understandable. For there is no reason why we should expect a positive correlation between the relative yield and relative price. This is because yield is influenced by a combination of factors such as capital rationing, physical unavailability of inputs at the right time, limitations imposed by uncertainty, and even ignorance of better farming methods. Further, relative yield response very much depends on the behaviour with respect to allocation of non-land inputs. However, we can safely draw the conclusion that increases in relative output are forthcoming more as a result of shifting crop acreages than as a result of a rise in relative yields. This conclusion is also substantiated by equations VIII and IX which show that as between acreage and yield relative output is significantly correlated with acreage. This also means that since output and acreage are moving symmetrically, farmers are allocating in addition to land, other complementary non-land inputs also to a large extent. In most studies, it is assumed that inputs other than land vary proportionately with acreage. In the present study, however, non-land inputs are increasing less than proportionately with increasing acreage. Hence the response of relative output turns out to be lower than the response of relative acreages (see equations I and IV).

Equations VI and VII involve slight reformulation of the original hypothesis. In equation VI, relative price and relative yield (both lagged by one year) are entered as independent variables, since this year's relative acreage depends not only on last year's relative price but also on relative yield. This improves the explanation of change in relative acreage. Equation VII is a further extension of the same reasoning. Lagged yields of both crops were multiplied by respective prices to obtain gross income per acre from each of the crops. Gross income of sugarcane was deflated by that of rice, and relative income was entered as an independent variable along with lagged relative acreage. The explanation further improves to 0.59, and both coefficients are significant.

In the above equations, we have used lagged relative price as the main explanatory variable for acreage response. This is based on the assumption that farmers' expectations regarding current year's prices may be influenced by the price situation last year. Indeed it is possible that farmers might in fact be responding in this fashion to some extent, as our results have shown. But is such "responsiveness" also a "rational responsiveness"? This has been recently called in question.[2] If it is observed that previous year's price is not efficiently predicting the current year's direction of change in price, then even if farmers' acreage response to lagged price turns out to be positive, we cannot assert that such "responsiveness" is also "rational responsiveness." Since lagged relative price has been used in this study, an attempt has been made to test the predictive efficiency of lagged price. Equation X is an autoregression where $Pt-1$ and $Pt-2$ (relative prices) were entered as independent variables, and Pt as the dependent variable. This gives an interesting result. $Pt-1$ is positively predicting Pt, while $Pt-2$ has a negative sign. The fact that Pt and $Pt-1$ are positively correlated indicates that the farmers' acreage response observed in this study also seems to be "rational responsiveness."

Summary and Conclusion

It has been found that changes in relative acreage under sugarcane in Andhra Pradesh are positively associated with changes in its relative price. The explanation for the variation in relative acreage improves when the lagged relative yield is included as another independent variable. However, relative gross income per acre seems to explain better the changes in relative acreage. No measurable yield response was found, and from this we can infer that while a 10 per cent increase in relative price will result in at least 5 per cent increase in relative output, most of the increase in relative output would be the result of shifting land from rice, rather than by increasing the relative yield. The assumption that farmers divert non-land resources in the same proportion as land has been tested by regressing output against yield and acreage separately. Non-land inputs seem to move less than proportionately with acreage. Finally, the rationality of the farmers' response has been studied by testing the predictive efficiency of lagged relative price by means of an autoregression, which has been found to be positive.

K. SUBBARAO*

2 See Michael Lipton, "Should Reasonable Farmers Respond to Price Changes?," *Modern Asian Studies*, January, 1967. (This is a review article of Dharm Narain's book, *op. cit.*)

* Lecturer in Economics, P. G. D. A. V. College, University of Delhi, New Delhi.

POST-LIVESTOCK CENSUS SAMPLE SURVEY IN THE PUNJAB STATE

The Livestock Census provides detailed data on livestock classified according to broad age-groups, sex, etc. Data on their detailed age composition, breed, order and stage of lactation completed, etc., are needed for the purpose of planning the development programme and executing them. These data cannot be collected in the course of the census without affecting their quality. Thus, for the collection of this valuable information, a Post-Livestock Census Survey was conducted in the Punjab State during May-June, 1966.

The plan for the sample survey was one of multi-stage stratified sampling. In the rural area, a tehsil was the stratum while in the urban area a district was the stratum. From each district, a sample of 10 to 12 villages suitably allocated among the tehsils was selected with probability proportional to the number of households in the village according to the 1961 Census and with replacement. Similarly, a sample of 3 towns was selected with the probability proportional to the number of households in the urban area and with replacement. Altogether, 132 villages and 33 towns were selected. Two wards were selected from each of the selected towns. A sample of 20 households from each village and 25 households from each sample ward of the selected town was selected with equal probability. The sample was selected in clusters, each cluster comprising 5 households.

The field staff consisted of two field officers (District Animal Husbandry Officers) and 11 enumerators (Veterinary Assistant Surgeons). The statistical analysis of the data was carried out by the Statistical Cell of the Animal Husbandry Department.

RESULTS

Estimate of Cattle and Buffalo

It was estimated that during the period of the survey, there were about 31.53 and 30.97 lakh cows and buffaloes respectively in the reorganized Punjab State. These figures were estimated with percentage standard error of 6.9 and 6.1 respectively. Table I shows the estimated cattle and buffalo population with their standard errors in different categories.

Comparison with Census Estimates

In Table II are given estimates of the survey and of Census 1966 for different classes of animals among cattle and buffaloes. Sampling errors for the survey estimates are also presented for easy reference. It would be interesting to compare the estimated population of cattle and buffaloes as obtained in this survey with the number of cattle and buffaloes as reported in the Livestock Census, 1966. According to the 1966 Census, there were 31.19 and 29.36 lakh cows and buffaloes in the reorganized Punjab State.

The comparison of survey estimates with the Livestock Census number showed an increase of 1.07 and 5.47 per cent in cattle and buffaloes over the population reported in the Livestock Census. It can be seen from Table II that there was

TABLE I—ESTIMATED NUMBER OF COWS AND BUFFALOES IN DIFFERENT AGE-GROUPS IN RURAL AND URBAN AREAS

	Cows			Buffaloes		
	Rural	Urban	Total	Rural	Urban	Total
(a) *Male above Three Years*						
(i) Breeding bulls ..	10,463 (29.6)	365 (66.0)	10,828 (30.8)	6,627 (36.6)	548 (17.7)	7,175 (35.2)
(ii) Breeding-cum-working bulls	10,466 (25.5)	731 (28.3)	11,197 (25.7)	13,578 (25.6)	242 (57.4)	13,820 (26.2)
(iii) Castrated bullocks ..	11,73,947 (5.6)	60,081 (8.4)	12,34,028 (5.7)	11,799 (29.9)	1,268 (11.12)	13,067 (28.1)
(iv) Uncastrated bullocks	7,512 (32.9)	396 (48.4)	7,908 (33.7)	2,41,796 (4.1)	1,640 (24.7)	2,43,436 (3.7)
(v) Bulls used neither for breeding nor for work	5,282 (34.1)	— —	5,282 (34.1)	4,189 (37.2)	— (—)	4,189 (37.2)
Total ..	12,07,670 (6.1)	61,573 (9.5)	12,69,243 (6.4)	2,77,989 (7.7)	3,698 (22.8)	2,81,687 (7.8)
(b) *Female above Three Years*						
(i) Breeding cows ..	7,01,547 (6.19)	65,014 (13.3)	7,66,561 (6.8)	13,89,741 (5.0)	93,365 (8.4)	14,82,106 (5.2)
(ii) Breeding-cum-working cows	— (—)	— (—)	— (—)	12,584 (24.1)	— (—)	12,584 (24.1)
(iii) Working cows ..	— (—)	— (—)	— (—)	22,850 (13.7)	731 (51.9)	23,581 (14.7)
(vi) Cows used neither for breeding nor for work	16,597 (35.16)	365 (76.9)	16,962 (39.1)	19,428 (19.8)	— —	19,428 (19.8)
Total ..	7,18,140 (7.29)	65,379 (17.5)	7,83,523 (7.5)	14,44,603 (5.5)	94,096 (8.8)	15,37,699 (5.7)
(c) *Young Stock*						
(i) Between 1 to 3 years	4,74,040 (4.82)	26,816 (13.76)	5,00,856 (5.3)	5,89,958 (4.59)	24,983 (12.03)	6,14,938 (4.9)
(ii) Calves under one year	5,44,947 (8.14)	54,586 (13.12)	5,99,533 (8.6)	6,08,075 (7.09)	54,762 (8.69)	6,62,837 (7.2)
Total ..	10,18,987 (6.6)	81,402 (13.3)	11,00,389 (7.1)	11,98,030 (6.8)	79,745 (9.7)	12,77,775 (6.1)
Grand total	29,44,801 (6.5)	2,08,354 (12.5)	31,53,155 (6.9)	29,20,622 (6.0)	1,77,539 (9.5)	30,97,61 (6.11)

Figures in parenthesis are the percentage of standard errors.

no statistical significant divergence between the figures except in the categories of calves under one year among cattle. This divergence may partly be attributed to the time lag of one month between the survey and Census. The accuracy of the Census figures is frequently questioned and opinion has been expressed that the *patwari* who is entrusted with enumeration work does not pay sufficient attention

TABLE II—COMPARISON OF SURVEY ESTIMATES WITH THOSE GIVEN BY PATWARI AGENCY IN LIVESTOCK CENSUS : 1966

	Survey estimate ('000)	Census estimate ('000)	Percentage of excess (+) or decrease (—) of Census over survey	Percentage S.E. of the survey estimate
Cattle				
Male over 3 years	1269.2	1267.9	—0.10	(7.7)
Female over 3 years	783.5	820.6	4.52	(7.5)
Young stock between 1 to 3 years	501.0	550.2	8.94	(5.3)
Calves under one year	599.5	481.0	—24.64	(8.6)
Total	3153.2	3119.7	—1.07	(6.9)
Buffaloes				
Male over 3 years	281.7	251.5	—12.01	(7.8)
Female over 3 years	1537.7	1490.0	— 3.20	(5.7)
Young stock between 1 to 3 years	614.9	588.8	— 4.43	(4.9)
Calves under one year	662.9	608.1	— 9.01	(7.2)
Total	3097.2	2936.4	— 5.47	(6.1)

to this work. The results given here show that the Livestock Census gives reliable information at least for broad categories of livestock at the State level.

The percentage distribution of cattle and buffaloes according to breeds and classes is given in Table III.

TABLE III—PERCENTAGE DISTRIBUTION OF CATTLE AND BUFFALOES ACCORDING TO BREEDS AND CLASSES

	Cattle					
Classification of breed	Sahiwal	Red-Sindhi	Hariana	Tharparkar	Non-descript	Others
Below 3 years	3.17	0.28	55.94	0.06	38.80	1.74
Female over 3 years	2.36	0.15	54.94	0.15	41.40	1.00
Male over 3 years	0.35	0.15	56.80	0.89	41.55	0.25
Overall	1.85	0.20	56.03	0.41	40.56	0.95

	Buffaloes			
	Murrah	Nili	Ravi	Non-descript
Below 3 years	39.06	20.78	3.98	36.17
Female over 3 years	38.94	19.09	3.94	38.03
Male over 3 years	28.27	8.94	1.87	61.92
Overall	37.94	18.73	3.75	39.58

From Table III it is clear that 56.03 per cent of the cattle were of Hariana breed, 40.56 per cent of non-descript, 1.85 per cent of Sahiwal, 0.41 per cent of Tharparkar, 0.20 per cent of Red-Sindhi and the rest were of other breeds. The "Others" include the cross breeds of Sahiwal, Red-Sindhi, Tharparkar, etc., with non-descript cattle.

In the case of buffaloes, 37.94 per cent were of Murrah, 18.73 per cent of Nili, 3.75 per cent of Ravi breed and 40.15 per cent of non-descript type.

Distribution of Cows in Different Lactations

During the course of survey, information on the order of lactation of cows and buffaloes in milk was also obtained. The percentage number of animals observed in different lactations is given in Table IV.

TABLE IV

Order of lactation	No. of animals observed		Percentage number of animals	
	Cattle	Buffaloes	Cows	Buffaloes
1.	201	128	17.85	15.04
2.	278	143	24.69	61.80
3.	232	149	20.60	17.51
4.	190	124	16.87	14.57
5.	100	120	8.88	14.10
6.	62	89	5.50	10.46
7.	19	36	1.69	4.23
8.	22	34	1.95	3.99
9.	16	13	1.42	1.53
10.	4	13	0.36	1.53
11.	2	1	0.18	0.12
12.	—	1	—	0.12
	1126	851		

From Table IV it is evident that about 80 per cent of cows were either in 4th or less than 4th lactation. In the case of buffaloes, 78 per cent of the animals were either in the 5th or less than 5th lactation.

Age at First Calving and Calving Interval

The results presented in Table V indicate the average age at first and second calvings for different breeds in rural areas. An interesting result is the relatively early maturity of the non-descript cows and buffaloes which matured earlier than the other breeds of cows and buffaloes. Cows of non-descript breed matured earlier than the Sahiwal and Hariana by about two months. In the case of buffaloes, non-descript type matured earlier by 3 months than the Murrah breed. In respect of cows, the estimated average calving interval between the first and second calving was 15.08 months for Hariana, 18.33 months for Sahiwal and 16.49 months for non-descript cows. This period for buffaloes was found to be 15.83 months for Murrah, 14.65 months for Nili breed and 19.04 months for a non-descript buffalo.

TABLE V—AVERAGE AGE AT DIFFERENT CALVINGS FOR DIFFERENT BREEDS IN RURAL AREAS

Breed	First calving			Second calving			Calving interval	
	No. of animals observed	Average age in months	S.E. months	No. of animals observed	Average age in months	S.E. months	Average months	S.E. months
Cows								
Hariana	—	52·44	0·4	—	67·52	0·4	15·08	0·5
Sahiwal	—	52·50	0·5	—	71·33	0·5	18·33	0·5
Non-descript.. ..	—	50·41	0·5	—	66·98	0·5	16·49	0·7
Buffaloes								
Nili	—	51·48	0·5	—	66·13	0·6	14·65	0·9
Murrah	—	54·76	0·3	—	70·59	0·3	15·83	0·4
Non-descript ..	—	51·27	0·7	—	70·31	0·8	19·04	1·1

Season of Calvings

The data collected during the survey on the stage of lactation of each animal in milk was analysed and the results showing the frequency distribution of animals according to the month of calving are shown in the Table VI.

TABLE VI—RELATIVE FREQUENCY DISTRIBUTION OF ANIMALS ACCORDING TO MONTHS OF CALVING

Month	No. of animals observed		Percentage of calvings	
	Cows	Buffaloes	Cows	Buffaloes
January	155	42	13·75	4·97
February	143	28	12·67	3·34
March	124	21	10·99	2·51
April	129	28	11·49	3·29
May	112	37	9·99	4·36
June	86	55	7·61	6·46
July	70	108	6·19	12·70
August	63	125	5·58	14·71
September	58	144	5·15	16·87
October	61	128	5·37	15·02
November	48	77	4·31	8·97
December	77	58	6·89	6·79
	1126	851		

Nearly 49 per cent of cows calved during the period of January to April, while the rest of calvings took place in the period May to December. However, in the case of buffaloes about 69 per cent of animals calved during July to October.

Distribution of Animals in Different Age-Groups

During the course of the survey information on the age of the animals was also recorded. The percentage number of animals found in different age-groups is given in Tables VII and VIII.

TABLE VII—PERCENTAGE NUMBER OF ANIMALS—YOUNG STOCK

Age-group	Cows				Buffaloes			
	Male		Female		Male		Female	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Up to 2 months ..	15·57	25·14	17·82	25·31	6·36	14·68	6·05	8·47
Over 2 months up to 6 months	16·54	23·95	20·46	18·98	15·67	23·85	14·38	26·27
Over 6 months up to 12 months	21·18	25·14	15·84	15·19	28·29	29·81	20·55	34·74
Over 12 months up to 24 months	30·02	17·97	16·17	32·91	31·39	21·56	32·19	16·95
Over 24 months up to 36 months	16·68	7·79	29·70	7·59	18·28	10·09	26·82	13·56

From Table VII it is evident that in the rural area 53 and 50 per cent of male calves of cows and buffaloes respectively were of the age under 12 months; whereas in the urban area, 74 and 68 per cent of calves were in this age-group. Similarly, 54 and 41 per cent of female calves of cows and buffaloes respectively in the rural area were of the age under 12 months. In case of urban area, 59 and 69 per cent were in this age-group.

TABLE VIII—PERCENTAGE NUMBER OF COWS AND BUFFALOES (FEMALES OVER THREE YEARS)

Age-group	Cows		Buffaloes	
	Rural	Urban	Rural	Urban
Over 36 months to 48 months	13·40	10·50	10·87	7·38
Over 48 months to 60 months	12·38	13·70	10·32	6·48
Over 60 months to 72 months	19·20	22·37	13·31	15·38
Over 72 months to 84 months	16·07	13·24	15·28	14·77
Over 84 months to 96 months	15·04	20·55	18·02	23·38
Over 96 months to 108 months	8·70	7·31	10·96	13·85
Over 108 months to 120 months	6·90	6·85	10·02	10·15
Over 120 months to 132 months	2·82	1·83	3·64	3·38
Over 132 months to 144 months	1·88	1·83	3·21	3·08
Over 144 months to 156 months	1·18	0·91	1·67	—
Over 156 months to 168 months	0·86	—	0·98	0·62
Over 168 months to 180 months	0·70	0·45	0·82	0·92
Over 180 months to 192 months	0·39	—	0·21	0·62
Over 192 months to 204 months	0·08	—	0·04	—
Over 204 months	0·39	0·45	0·64	—

It is revealed from Table VIII that in the rural area, 76 and 67 per cent of cows and buffaloes respectively were under the age of 96 months (8 years). In the urban area, 80 and 67 per cent of cows and buffaloes were in this age-group.

The average age of cows in the rural and urban area was 77.88 ± 0.68 and 78.93 ± 1.10 month respectively. In the case of buffaloes, it was 85.54 ± 0.62 in the rural area and 87.27 ± 1.47 in the urban area.

SUDARSHAN KUMAR*

* Survey and Evaluation Officer, Directorate of Animal Husbandry, Punjab, Chandigarh.

NOTE ON APPLICATION OF PROGRAMMING TECHNIQUES TO INDIAN FARMING CONDITIONS—A REPLY

A. S. Kahlon and S. S. Johl have tried to explain a few issues raised by me in the review of their brochure: Application of Programming Techniques to Indian Farming Conditions.[1] Their main contention is that I have not appreciated one of the major contributions made by them in solving the linear programming problem in the context of Indian agriculture.

What I had objected to was the inconsistency between what is stated as realistic constraints and the way these constraints were related to the activities in the simplex tableau form. One of the important aspects in the application of programming techniques is to frame the initial tableau. In order to show the inconsistency between the stated aspects of the realistic constraints of land classifications and the initial tableau they have framed, I shall have to reproduce the abstracts from their brochure.

The authors have given the classification of plots as follows[2]:

Plot		Area (acres)	Suitability for different crops
Rabi season			
A_r	..	5.00	Land suitable for sugarcane, all *rabi* fodders and wheat but not for gram.
B_r	..	0.90	Land suitable for wheat only and not for gram or fodders or sugarcane.
C_r	..	2.50	Land suitable for gram and wheat but not for sugarcane and fodder.
Kharif season			
A_k	..	5.00	Land suitable for sugarcane, cotton and maize and not for groundnut.
B_k	..	1.50	Land suitable for maize and cotton but not for sugarcane or groundnut.
C_k	..	2.25	Land suitable for groundnut only.

On page 18 of the brochure, the authors have given the table as follows :

TABLE I.1—MATRIX OF LAND INPUT COEFFICIENTS FOR DIFFERENT CROP ENTERPRISES

Land category	Average level (acres)	Wheat after fallow	Wheat after *kharif*	Gram irrigated	Maize after fallow	Maize after *rabi*	American cotton after *rabi*	American cotton after fallow	*Desi* cotton	Sugarcane	Groundnut
Wheat land irrigated $(A + B + C)_r$ ..	8.40	1	1	1	1	0	0	1	0	1	0
Gram land irrigated C_r	2.50	0	0	1	0	0	0	0	0	0	0
Sugarcane land A_r ..	5.00	0	0	0	0	0	0	0	0	1	0
Maize and cotton land $(A + B)k$	6.50	1	0	0	1	1	1	1	1	1	0
Sugarcane land A_k ..	5.00	0	0	0	0	0	0	0	0	1	0
Groundnut land C_k ..	2.25	0	0	0	0	0	0	0	0	0	1

1. This *Journal*, Vol. XXIII, No. 3, July-September, 1968, pp. 54-56.
2. Application of Programming Techniques to Indian Farming Conditions, 1967, p. 11.

If we read the rows from the table they will read as follows :

1. Wheat after fallow or *kharif* can be grown to the maximum limit of 8.40 acres.

2. Gram irrigated can also be grown to the maximum limit of 8.40 acres. This is inconsistent with what is stated earlier that A_r and B_r lands are not suitable for gram.

3. Similarly, land suitable for American cotton is A^k (5.00) + B_k (1.50) = 6.50 acres whereas the row states that American cotton after fallow can be grown to the maximum limit of 8.40 acres.

4. In the case of sugarcane, the total area suitable for growing this crop is A_r = 5.00 acres whereas the row states that it can be grown up to the maximum limit of 8.40 acres.

5. Again sugarcane cannot be grown on all maize and cotton land but row 4 of Table I.1 suggests that the maximum limit for sugarcane is maize and cotton land $(A + B)_k$.

In order to remove this inconsistency between the statements about the realistic constraints and the tableau, I had suggested that it could be framed differently. Unfortunately, my tableau is also inconsistent with the statements of constraints. Although it is consistent while reading along the rows, it is inconsistent if we read along the columns. For example, wheat after fallow (W) is dominantly restricted by B , if we put the coefficient under the same column whereas the realistic restriction is $A_r + B_r + C$. In order that the constraints as stated on page 11 of the brochure are properly transcribed in the tableau form, the following tableau should be used.

INITIAL TABLEAU[3]

Activities		b_i	C_j	Wheat after fallow 329 P_1	Wheat after fallow 329 P_2	Wheat after fallow 329 P_3	Wheat after *kharif* 270 P_4	Wheat after *kharif* 270 P_5	Wheat after *kharif* 270 P_6	Gram irrigated 167 P_7	Maize after fallow 319 P_8	Maize after fallow 319 P_9
Land	A_r	b_1	5.00 (acres)	1	0	0	1	0	0	0	0	0
Land	B_r	b_2	0.90 (acre)	0	1	0	0	1	0	0	0	0
Land	C_r	b_3	2.50 (acres)	0	0	1	0	0	1	1	0	0
Land	A_k	b_4	5.00 (acres)	0	0	0	0	0	0	0	1	0
Land	B_k	b_5	1.50 (acres)	0	0	0	0	0	0	0	0	1
Land	C_k	b_6	2.25 (acres)	0	0	0	0	0	0	0	0	0
Labour (Mid-March—mid-April)		b_7	350 (mds.)	0	0	0	0	0	0	30	0	0
Labour (Mid-April—end of April)		b_8	204 (mds.)	20	20	20	20	20	20	0	0	0
Labour (Mid-October—mid-November)		b_9	360 (mds.)	24	24	24	24	24	24	0	8	8
Labour (Mid-November—mid-March)		b_{10}	1195	64	64	64	64	64	64	4	0	0

(Contd.)

INITIAL TABLEAU—(*Concld.*)[3]

Activities	b_i	C_j	Wheat after fallow 329 P_1	Wheat after fallow 329 P_2	Wheat after fallow 329 P_3	Wheat after *kharif* 270 P_4	Wheat after *kharif* 270 P_5	Wheat after *kharif* 270 P_6	Gram irrigated 167 P_7	Maize after fallow 319 P_8	Maize after fallow 319 P_9
Cotton (maximum)	b_{11}	2.50 (acres)	0	0	0	0	0	0	0	0	0
Irrigation (maximum)	b_{12}	4.90 (acres)	0	0	0	0	0	0	0	0	0
Farmyard manure	b_{13}	40 (tonnes)	0	0	0	0	0	0	0	8	8
Kharif capital	b_{14}	150 (Rs.)	0	0	0	0	0	0	0	7	7
Rabi capital	b_{15}	130 (Rs.)	19	19	19	18	18	18	7	0	0

Activities		b_i	C_j	Maize after *rabi* 264 P_{10}	Maize after *rabi* 264 P_{11}	American cotton after *rabi* 390 P_{12}	American cotton after *rabi* 390 P_{13}	American cotton after fallow 510 P_{14}	American cotton after fallow 510 P_{15}	*Desi* cotton with respect to A_k 320 P_{16}	*Desi* cotton with respect to B_k 320 P_{17}	Sugarcane 774 P_{18}	Groundnut 340 P_{19}
Land	A_r	b_1	5.00 (acres)	0	0	0	0	0	0	0	0	1	0
Land	B_r	b_2	0.90 (acre)	0	0	0	0	0	0	0	0	0	0
Land	C_r	b_3	2.50 (acres)	0	0	0	0	0	0	0	0	0	0
Land	A_k	b_4	5.00 (acres)	1	0	1	0	1	0	1	0	1	0
Land	B_k	b_5	1.50 (acres)	0	1	0	1	0	1	0	1	0	0
Land	C_k	b_6	2.25 (acres)	0	0	0	0	0	0	0	0	0	1
Labour (Mid-March—mid-April)		b_7	350 (mds.)	0	0	0	0	12	12	0	0	44	0
Labour (Mid-April—end of April)		b_8	204 (mds.)	0	0	0	0	0	0	0	0	8	0
Labour (Mid-October—mid-November)		b_9	360 (mds.)	8	8	0	0	0	0	0	0	10	48
Labour (Mid-November—mid-March)		b_{10}	1195	0	0	0	0	0	0	0	0	500	0
Cotton (maximum)		b_{11}	2.50 (acres)	0	0	1	1	1	1	1	1	0	0
Irrigation (maximum)		b_{12}	4.90 (acres)	0	0	1	1	1	1	1	1	1	0
Farmyard manure		b_{13}	40 (tonnes)	10	10	12	12	8	8	8	8	10	0
Kharif capital		b_{14}	150 (Rs.)	7	7	10	10	10	10	10	10	16	56
Rabi capital		b_{15}	130 (Rs.)	0	0	0	0	0	0	0	0	50	0

3. This tableau is framed from the data given on pages 11, 16, 20 and 21 of the brochure. The readers of the brochure would immediately understand the difficulties of deciphering the notations used by the authors without explaining them in the text.

Activities		Notations
(1) Wheat after fallow with respect to A_r	..	P_1
(2) Wheat after fallow with respect to B_r	..	P_2
(3) Wheat after fallow with respect to C_r	..	P_3
(4) Wheat after *kharif* with respect to A_r	..	P_4
(5) Wheat after *kharif* with respect to B_r	..	P_5
(6) Wheat after *kharif* with respect to C_r	..	$P_{\prime}$
(7) Gram irrigated	..	P_7
(8) Maize after fallow with respect to A_k	..	P_8
(9) Maize after fallow with respect to B_k	..	P_9
(10) Maize after *rabi* with respect to A_k	..	P_{10}
(11) Maize after *rabi* with respect to B_k	..	P_{11}
(12) American cotton after *rabi* with respect to A_k	..	P_{12}
(13) American cotton after *rabi* with respect to B_k	..	P_{13}
(14) American cotton after fallow with respect to A_k	..	P_{14}
(15) American cotton after fallow with respect to B_k	..	P_{15}
(16) *Desi* cotton with respect to A_k	..	P_{16}
(17) *Desi* cotton with respect to B_k	..	P_{17}
(18) Sugarcane with respect to A_r and A_k	..	P_{18}
(19) Groundnut	..	P_{19}

Constraints		Notations			
(1) Land suitable for sugarcane, all *rabi* fodder and wheat but not for gram	..	A_r	b_1		5.00 (acres)
(2) Land suitable for wheat only and not for gram or fodders or sugarcane	..	B_r	b_2		0.90 (acre)
(3) Land suitable for gram and wheat but not for sugarcane and fodder	..	C_r	b_3		2.50 (acres)
(4) Land suitable for sugarcane, cotton and maize and not for groundnut	..	A_k	b_4		5.00 (acres)
(5) Land suitable for maize and cotton but not for sugarcane or groundnut	..	B_k	b_5		1.50 (acres)
(6) Land suitable for groundnut only	..	C_k	b_6		2.25 (acres)
(7) Mid-March to mid-April labour	..		b_7	=	350 (maunds)
(8) Mid-April to end of April labour	..		b_8	=	204 (maunds)
(9) Mid-October to mid-November labour	..		b_9	=	360 (maunds)

(Contd.)

Constraints		Notations
(10) Mid-November to mid-March labour	..	b_{10} = 1195 (maunds)
(11) Cotton maximum	..	b_{11} = 2.50 (acres)
(12) Irrigation maximum	..	b_{12} = 4.90 (acres)
(13) Farmyard manure	..	b_{13} = 40 (tonnes)
(14) *Kharif* capital	..	b_{14} = 150 (Rs.)
(15) *Rabi* capital	..	b_{15} = 130 (Rs.)

The results obtained using this initial tableau are compared with those obtained by Kahlon and Johl as follows :

COMPARISON OF THE FINAL SOLUTION

Activities	Levels of activities according to	
	Desai (acres)	Kahlon and Johl (acres)
Wheat after fallow	5.93	2.00
Wheat after *kharif*	—	3.22
Maize after fallow	2.50	—
Maize after wheat	—	1.32
American cotton after fallow	2.50	2.50
Groundnut	1.92	1.87
Sugarcane	—	0.68
Net cash income (Rs.)	5,089	4,314

COMPARISON OF SHADOW PRICES OBTAINED IN THE FINAL SOLUTION

Constraints			Marginal value products according to	
			Desai (Rs.)	Kahlon and Johl (Rs.)
Land	A_r	b_1	72.5	165.75
Land	B_r	b_2	72.5	
Land	C_r	b_3	72.5	
Land	A_k	b_4	—	53.1
Land	B_k	b_5	1.5	
Land	C_k	b_6	—	—
Labour—Mid-March to mid-April ..		b_7	—	—
Labour—Mid-April to end of April ..		b_8	—	—
Labour—Mid-October to mid-November		b_9	—	—
Labour—Mid-November to mid-March		b_{10}	—	—
Cotton maximum		b_{11}	172.78	95.70
Irrigation maximum		b_{12}	—	—
Farmyard manure		b_{13}	34.56	16.83
Kharif capital		b_{14}	6.07	6.07
Rabi capital		b_{15}	13.49	5.80

It will be observed that the formulation of the problem in the revised form which is consistent with the constraints has increased the net cash income by Rs. 775 from Rs. 4,314 to Rs. 5,089. The shadow prices of the constraints also have changed. What is important is not that the income is increased but the problem has become consistent with the stated facts. In linear programming problems, the most important aspect is the formulation of the problem itself. If any mistake is advertently or inadvertently made, the result would not be consistent with the stated facts.

The interesting aspect of the present exchange of notes is that it has highlighted the difficulties of problem formulation.

As regards other clarifications given in the note, I leave it to the judgment of the readers whether the points raised by me in my review[4] are pertinent.

D. K. DESAI*

[With the publication of this reply, the correspondence on this subject is closed. (Ed.)]

4. See this *Journal*, Vol. XXIII, No. 1, January-March, 1968, pp. 91-94.

* Professor (Agriculture and Co-operation), Indian Institute of Management, Vastrapur, Ahmedabad-6.