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DECISION MAKING UNDER UNCERTAINTY WITH SPECIAL REFERENCE TO AGRICULTURE (IN INDIA)

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Uncertainty exists where an action or a number of actions have as consequence a set of possible specific outcomes the probabilities of which are completely unknown. In agriculture, weather (natural phenomenon as we may call it), is the major uncontrollable factor causing uncertainty. Some of the aspects of uncertainty caused by it have been successfully controlled, more so, in the developed countries as for example by control of insect pests, development of irrigation, etc. Still there are a number of factors which play their role in causing uncertainty. The impact of weather in the uncertainty complex is all the more great in the less developed countries. As for instance, farming is still a gamble in more than half of the area in India, where the raising of crops entirely depends upon the vagaries of rainfall.

Price fluctuations and technology developments are other factors causing uncertainty. The variations in the prices have been controlled in many countries within reasonable limits through government measures. The changes in technology generally are not very fast and abrupt in agriculture, especially in less developed countries.

The purpose of this paper is to examine the decision making criteria mainly for the uncertainty caused by natural factors. The study has been divided into two parts : (*i*) Decision making criteria and their implications, and (*ii*) some applications of the decision making criteria at the national, regional and individual levels.

I. DECISION MAKING CRITERIA AND THEIR IMPLICATIONS

Let us start with a pay-off matrix as below :

Pay-off Matrix

S/A	S_1	S_2	—	—	S_n
A_1	a_{11}	a_{12}	—	—	a_{1n}
A_2	a_{21}	a_{22}	—	—	a_{2n}
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
A_m	a_{m1}	a_{m2}	—	—	a_{mn}

Rows, i=1, 2......m Columns, J=1, 2......n

It is assumed in the above pay-off matrix that states of nature S_1, $S_2, \ldots S_n$ are known and they are independent (mutually exclusive). The possible acts are $A_1, A_2, \ldots A_m$, and the pay-off matrix is known. Two person zero sum game, where nature can be categorised as one player, is based on the idea of an opponent with a definite interest in reducing the partner's gains.[1] No such motive, however, can be ascribed to nature. The problem can be considered as one person game against nature which is neutral. Uncertainty exists so far as there is a 'complete ignorance' about the true state of nature.

Hurwicz,[2] as we shall see later, has suggested that partial ignorance over S, can be effectively processed to yield complete ignorance over some subset $Y^{(o)}$ of Y (Y is the set of all *a priori* probability distributions over S).

With this background, we may now discuss the decision criteria.

1. *The Maximin Criterion (Wald)*[3]

Each act A_i is appraised by its security level. The security level for an act A_i is the minimum number among $a_{i1}, a_{i2}, \ldots a_{in}$. The act with the maximum security level is chosen. The principle is, therefore, called maximin.

Considering the nature as the second player and the pay-off as its losses, the nature may be taken as a minimizing player, whose strategy will be to minimise the maximum loss. Each state S_j is assigned an index, the maximum number among $a_{1j}, a_{2j}, \ldots a_{mj}$. Then the state with minimum index is chosen.

In the context of two person zero sum game, the second player is assigned a definite objective to minimize the losses to it which are, on the other hand, gains of the first player. The principle is, therefore, called minimax—minimizing the maximum loss—strategy of the second player. As stated earlier, no such definite objective can be ascribed to nature for attempting to provide 'least favourable' *a priori* distribution to the farmers. However taking the nature as the second player, the following possibilities will arise.

(*i*) Saddle point exists :

If $\min_j (\max_i a_{ij}) = \max_i (\min_j a_{ij})$

then equilibrium pair exists, its value may be denoted by $a_{i_o j_o} = V$. An equilibrium strategy not only attains the best security level for Player I, but it is good against that strategy of Player II, which attains his best security level. Though the concept of Saddle point may not apply when we take the nature as the neutral player, the maximin principle, being conservative one, may be useful in a number of problems.

1. J. Von Newmann and O. Margenstern: Theory of Games and Economic Behaviour (1944), 1947, pp. 98-100, 200.
2. Leonid, Hurwicz "Some Specifications Problems and Applications to Econometric Models," *Econometrica*, 19 : 343-344, 1951.
3. A. Wald ; Statistical Decision Functions, 1950.

(*ii*) Saddle point does not exist and mixed strategy is possible :

If it is possible to reduce the pay-off matrix by elimination of dominated rows and dominating columns into 2 x 2 matrix, the following procedure could be employed.

		q	1-q
		S_1	S_2
P	A_1	a_{11}	a_{12}
1-P	A_2	a_{21}	a_{22}

$$P\,(a_{11}) + (1\text{-}P)\,a_{21} = V$$

$$P\,(a_{12}) + (1\text{-}P)\,a_{22} = V$$

$$P\,(a_{11}) + (1\text{-}P)\,a_{21} = P\,(a_{12}) + (1\text{-}P)\,a_{22}$$

The value of P can be determined by the above equations. The same procedure can be applied to work out q for Player II.

In case it is not possible to reduce the pay-off matrix into 2 x 2, the linear programming technique[4] can be used for finding the mixed strategy.

Pay-off Matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & . & . & . & a_{1n} \\ a_{21} & a_{22} & . & . & . & a_{2n} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ a_{m1} & a_{m2} & . & . & . & a_{mn} \end{bmatrix}$$

The problem is to solve inequalities.

1. $AQ \leqslant V$ for minimizing player
2. $A'P \geqslant V$ for maximizing player

Q is the vector of relative frequencies for Player II, and P for Player I, V is defined earlier.

The restriction for inequalities II is $\sum_{i=1}^{m} p_i = 1, \quad 0 \leqslant p_i \leqslant 1$

4. Earl O. Heady and W. V. Candler : Linear Programming Methods, 1958, Ch. 14.

The restriction for inequalities I, is $\sum_{j=1}^{n} q_j = 1, \qquad 0 \leqslant q_j \leqslant 1$

Taking Player II as an example, we can transform the problem into linear programming as :

Max:

$$\frac{q_1}{v} + \frac{q_2}{v} + \ldots + \frac{q_n}{v} = \frac{1}{v}$$

Subject to

$$\frac{a_{11} q_1}{v} + \frac{a_{12} q_2}{v} + \ldots + \frac{a_{1n} q_n}{v} \leqslant 1$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$\frac{a_{m1} q_1}{v} + \frac{a_{m2} q_2}{v} + \ldots + \frac{a_{mn} q_n}{v} \leqslant 1$$

The solution for either player provides the necessary solution for the other, because of the dual property of the linear programming solution. The solution can be obtained by applying the Simplex Method. Maximising $\frac{1}{V}$ is equivalent to minimizing V, the strategy of the second player in our example.

(*iii*) Saddle point does not exist and mixed strategy is not permissible. The maximin in this case will indicate the desirable act.

The main criticism of the criterion is that it concentrates on the state having the worst consequences. As we shall see later, it may be applicable in quite a number of situations.

2. *The Minimax Risk Criterion (Savage)*[5]

It is based on the reason that the decision maker tries to minimize his regret. The regret (risk) matrix is constructed as follows from the pay-off matrix.

v_{ij} is defined as the amount that has to be added to a_{ij} to make it equal the maximum pay-off in the jth column.

$$v_{ij} = \text{Max}_j \; a_{ij} - a_{ij}$$

The act which minimizes the maximum regret is chosen in the case of pure strategy. If regret matrix has no Saddle point and the mixed strategy is permissible, the solution can be obtained by applying linear programming technique. This criterion is also considered as conservative one.

5. L. J. Savage; "The Theory of Statistical Decision," *Journal of American Statistical Association*, 46:55-57, 1951.

In criticism of the criterion, it is appropriate to mention the points raised by Chernoff.[6]

(i) It has never been clearly demonstrated that differences in utility (pay-off) do in fact measure what we may call regret. In other words, it is not clear that the 'regret' of going from a state of utility 5 to a state of utility 3 is equivalent in some sense of going from a state of utility 11 to one of utility 9.

(ii) One may construct examples where an arbitrarily small advantage in one state of nature outweighs a considerable advantage in another state. Such examples tend to produce the same feeling of uneasiness which led many to object to minimax risk.

(iii) In some examples the minimax regret criterion may select a strategy (act) d_3 among the available strategies d_1, d_2, d_3 and d_4. On the other hand, if for some reasons d_4 is made unavailable, the minimax regret criterion will select d_2 among d_1, d_2 and d_3. The author feels that for a reasonable criterion, the presence of undesirable strategy d_4 for a reasonable criterion should not have an influence on the choice among the remaining strategies.

3. *Pessimism-Optimism Index Criterion of Hurwicz*[7]

The maximin Wald criterion and minimax risk criterion lay stress for each act upon the state of nature with worst consequences. These criteria are, therefore, considered as conservative ones. Hurwicz suggests through his Pessimism-Optimism criterion that both the states with the best and the worst consequences for each act may be considered for decision making.

The minimum and maximum pay-off numbers for an act A_i may be represented by m_i and M_i respectively. Further the Pessimism-Optimism index α varying between 0 and 1 is assumed to be given for each act. The α-index for each act A_i is worked out as

$$\alpha\, m_i + (1-\alpha)\, M_i$$

The act with the highest α-index is selected.

If $\alpha = 1$, it reduces to maximin (Wald) criterion and if $\alpha = 0$ to minimax criterion. Luce and Raiffa[8] suggest a procedure for selecting α.

6. Herman Chernoff: "Rational Selection of Decision Functions," *Econometrica*, 22: 422-444, 1954.

7. Leonid Hurwicz : Optimality Criteria for Decision Making Under Ignorance, Cowles Commission, Discussion Paper No. 355, 1951.

8. R. D. Luce and H. Raiffa : Games and Decisions : Introduction and Critical Survey, 1957.

Suppose the pay-off matrix :

$$\begin{array}{c} \\ A_1 \\ A_2 \end{array} \begin{array}{c} \begin{array}{cc} S_1 & S_2 \end{array} \\ \begin{pmatrix} 0 & 1 \\ x & x \end{pmatrix} \end{array}$$

The α indices for A_1 and A_2 are $1-\alpha$ and x respectively. Consequently if one can choose an x such that A_1 and A_2 are indifferent, then one can impute α-level to oneself.

Suppose[9] that the pay-off matrix for m_i and M_i,

$$\begin{array}{c} \\ A_1 \\ A_2 \end{array} \begin{array}{c} \begin{array}{cc} m_i & M_i \end{array} \\ \begin{pmatrix} 500 & 2{,}000 \\ 0 & 6{,}000 \end{pmatrix} \end{array}$$

which act out of A_1 and A_2 will be selected depends on the value of

$$\alpha(500) + (1-\alpha)\ 2{,}000 \gtrless (0) + (1-\alpha)\ 6{,}000$$

$\alpha > 8/9$ then A_1 should be selected

$\alpha < 8/9$ then A_2 should be selected

$\alpha = 8/9$ either one or some mixture of two could be selected.

The decision for selecting a strategy revolves around the α-index.

4. *The Criterion Based on the "Principles of Insufficient Reason"* (called as Laplace[10] Criterion)

This criterion suggests that if one is 'completely ignorant' about the probability distribution over states, then one should take as if all the states are equally likely to occur. The problem then can be transferred to that of risk by assigning uniform *a priori* probability distribution over states. The expected pay-off index for each act A_i, then is,

$$\frac{a_{i1} + a_{2} + \ldots\ldots + a_{in}}{n} = \sum_{i=1}^{n} \frac{a_{ij}}{n}$$

The act with the largest index is chosen.

9. J. L. Dillon and Earl O. Heady: Research Bulletin 485, Iowa State University of Science and Technology, October, 1960.
10. R. M. Thrall, C. H. Coombs and R. L. Davis (Eds.) : Decision Processes, 1957.

5. *The Case of Partial Ignorance*

Maximin criterion, minimax regret principle, Hurwicz $\propto$, and Laplace criterion are based on some notion of 'complete ignorance' about the occurrence of states of nature. In actual practice, the decision maker has some vague information concerning the true state. The problem lies then in between the domains of complete ignorance and risk.

Savage in his work[11] develops the subjective probability theory to deal with this situation. To do this, he synthesized de Finettis' personalistic approach to probability and Von Newmann's and Morgenstern's axiomatic approach to utility. He suggests that partial knowledge regarding states of nature can be utilized to generate a unique *a priori* distribution over the states of nature through ones responses to a series of hypothetical questions. If this subjective probability distribution could be generated, the decision problem then can be handled in subjective terms as a risk problem, provided only that the expected value of pay-off distributions are considered by the decision maker.

Hurwicz[12] on the other hand suggests that the case of partial ignorance about the states of nature can be converted into the problem of 'complete ignorance' about the probability distribution over states. If Y is a set of all *a priori* probability distributions for states of nature, it may be possible to eliminate certain *a priori* distributions for which our knowledge is adequate enough to reject them. The remaining *a priori* distribution Y° of Y may be treated as in the domain of complete ignorance.

Bayes' Theorem may be relevant to mention :

$$P(B_i/A) = P(A/B_i)\, P(B_i) \Big/ \left[\sum_{i=1}^{n} P(A/B_i)\, P(B_i)\right]$$

The *a posteriori* probability $P(B_i/A)$ depends on the *a priori* probabilities $P(B_i)$ of various hypotheses and on the probabilities $P(A/B_i)$ of the occurrence of the observed event A under the various hypotheses. Bayes'[13] Theorem shows how a new piece of information, will modify the previous judgment as to the uncertainties of a situation. In the present context, the *a priori* probabilities are the judgment of the relative uncertainty of various hypotheses made on the basis of all past information, while *a posteriori* probabilities are based on the judgment made with the aid of new information.

The Simon Theory of Satisficer

Simon[14] postulates that in complex situations of the real world, the decision maker simplifies the problem by considering not all possible alternatives but only some subset which is commensurate with his capabilities of solution. He also assumes that the decision maker behaves as a "Satisficer" seeking a course of action that is good enough rather than as a maximizer, seeking the best course of

11. L. J. Savage : The Foundations of Statistics, 1954.
12. Leonid Hurwicz : "Some Specification Problems and Applications to Econometric Models," *Econometrica*, 19:343-344, 1951.
13. Thomas Bayes : "An Essay Towards Solving a Problem in the Doctrine of Chances," Philosophical Transactions of the Royal Society of London, Vol. 53: 370-418, 1763.
14. H. A. Simon : Models of Man, 1957, pp. 200, 204 and 246-248.

action. The decision maker has some aspiration which he tries to attain. This level may change over time. So long as the chosen act meets the aspiration level of the decision maker, he is behaving in an intendedly rational manner in Simon's terms. The theory tries to explain how the decision makers actually act and not how they should act.

II. SOME APPLICATIONS OF DECISION CRITERIA

Some of the decision theories discussed earlier purport to explain the actual behaviour under conditions of uncertainty. Some try to give advice on the rational behaviour, and some, by implication attempt to do both. For giving an advice for a rational behaviour to attain an objective, the study, as to how the decisions are made earlier, is necessary. This sort of study may lead to the necessity of certain changes in the decision criteria or adjustments in the objective, or both. As an instance, the objective may be to increase agricultural production. It would need the knowledge of the decision criteria being adopted by different farming units and how these can be rationalized to achieve the declared objective. The same process may be helpful at the macro level in framing objectives and working out policies involving uncertainty complex. Let us examine the data pertaining to fertilizer trials[15] in India.

1. *Macro Level*

Application of fertilizers is one of the important inputs considered in increasing agricultural production speedily. The responses to different doses of nitrogenous and phosphatic fertilizers and their combinations have been studied on the bases of large number of field trials conducted on cultivators' fields in the eleven regions, spread all over the country, for the two major crops, paddy (rice) and wheat over a period of 1953-54 to 1955-56. The average response in maunds per acre for the fertilizer applications is given in Appendix I.

The pay-off matrix, each for paddy (rice) and wheat, taking the prices of these commodities and those of fertilizers as constant, is constructed as under.

PAY-OFF MATRIX (NET INCOME) FOR FERTILIZER APPLICATION FOR PADDY

(in Rupees)

Doses	Year			Minimum of Row	Average for each Row
	1953-1954	1954-1955	1955-1956		
1. 20 (lb.) N	16.6	41.8	39.4	16.6	32.6
2. 40 (lb.) N	20.0	57.2	59.6	20.0	45.6
3. 20 (lb.) N	16.2	36.6	19.8	16.2	24.2
4. 20 (lb.) N + 20 (lb.) P ..	26.8	53.2	48.4	26.8	42.8
5. 20 (lb.) N + 40 (lb.) P ..	21.4	41.8	45.4	21.4	36.2
6. 40 (lb.) N + 20 (lb.) P ..	24.2	45.8	61.4	24.2	43.8
Maximum of Column ..	26.8	57.2	61.4		

Criteria	Fertilizer dose	Security level (Rs.)
Wald	20 (lb.) N + 20 (lb.) P	26.8
Laplace	40 (lb.) N	45.6

15. (1) Fertilizers Trials on Wheat, 1953-56; (2) Fetilizers Trials on Paddy, 1953-56, published by Indian Council of Agricultural Research, New Delhi.

States of nature are indicated by years. The natural conditions pertaining in a year, such as rainfall and weather, thus correspond to a state of nature in our case. It may, however, be noted that these three years under reference do not provide an exhaustive enumeration of the states of nature, in any general problem of decision making. Nevertheless, for the purpose of illustration, we assume them to constitute an exhaustive enumeration, and discuss the implications of decision making under uncertainty.

The Wald criterion gives the dose (20 (lb.) N + 20 (lb.) P) and there exists a Saddle point. The Laplace criterion indicates 40 (lb.) N. The security level according to Wald criterion is Rs. 26.8 whereas the value according to Laplace criterion is Rs. 45.6. It will be interesting to note the result of the production function fitted to the same data and reported in the Report on Fertilizers Trials.[16]

$$Y = 21.46 + 0.2675\,N - 0.0026\,N^2 + 0.2054\,P - 0.0016\,P^2 - 0.0029NP$$

The optimum dose as given by the above production function is 27 (lb.) N+ 20 (lb.) P.

The optimum dose derived from the production function is quite close to one given by Wald criterion. Now if the policy maker bases his value of the return per acre on either Laplace or the optimal dose value without looking at the confidence interval, the realized value in any single year may be far away from it. In situations where uncertainty complex is very important, Wald solution helps in estimating rock bottom of the return in a single year.

We may also look at the regret matrix constructed from the same data.

REGRET MATRIX FOR PADDY (RICE)

Doses	Year			Maximum of Row
	1953-54	1954-55	1955-56	
1. 20 (lb.) N	10.2	15.4	22.0	22.0
2. 40 (lb.) N	6.8	0	1.8	6.8
3. 20 (lb.) P	10.6	20.6	41.6	41.6
4. 20 (lb.) N + 20 (lb.) P	0	4.0	13.0	13.0
5. 20 (lb.) N + 40 (lb.) P	5.4	15.4	16.0	16.0
6. 40 (lb.) N + 20 (lb.) P	2.6	11.4	0	11.4

The pure strategy solution according to the Savage criterion is 40 (lb.) N, which is different from Wald criterion and same for Laplace criterion. There is no Saddle point.

With the improvement in the forecasting of weather with developments in meteorology science, and using data over a large number of years, it may be possible to generate the subjective probability over the states of nature. The subjective probability criterion, therefore, could be employed in certain cases.

16. *Ibid.*

It may be of interest to examine pay-off matrix for wheat as well.

PAY-OFF MATRIX (NET INCOME PER ACRE) FOR WHEAT

(in Rupees)

Doses	Year			Minimum of Row	Average of Row
	1953-54	1954-55	1955-56		
1. 20 (lb.) N	18.2	35.8	34.2	18.2	29.4
2. 40 (lb.) N	22.0	60.4	47.6	22.0	43.3
3. 20 (lb.) P	2.6	9.0	1.0	1.0	4.2
4. 40 (lb.) P	10.0	11.6	—1.2	—1.2	6.8
Maximum of Column ..	22.0	60.4	47.6		

The Wald and the Laplace criteria here give the same dose, 40 (lb.)N, and the values of game are Rs. 22.0 and Rs. 43.3 respectively.

The minimax risk criterion too determine the same dose.

REGRET MATRIX FOR WHEAT

Doses	Year			Maximum of Row
	1954-55	1955-56	1956-57	
1. 20 (lb.) N	3.8	24.6	13.4	24.6
2. 40 (lb.) N	0	0	0	0
3. 20 (lb.) P	19.4	51.4	46.6	51.4
4. 40 (lb.) P	12.0	48.8	48.8	48.8

2. *Farm Level*

The study of decision process at the farm level is very important especially for the extension service engaged in giving advice on the adoption of new technology, improved methods of farming, etc., and on adapting farms to the changing conditions. It is especially relevant in the less developed countries where very ambitious programmes have been launched and a number of measures are being taken to achieve the targets. The farms in the less developed countries are generally very small, of subsistence nature, without sufficient capital. The nature, on the other hand, plays a dominant role in determining the levels of outcomes. These factors may have influenced the farmers to develop conservative outlook and the attitude of risk aversion. The decision criteria applicable under these circumstances, for a number of problems may be conservative ones, namely, Wald maximin and Savage minimax regret criteria. But the recommendations to the farmers generally are based on the average results of experiments carried out at Research Stations under controlled conditions and in some cases further confirmed by trials on farmers' fields. The recommendations are mostly the same to every farmer in a particular region and thus can be categorized as blanket cover one. The approach as such seems very close to the Laplace criterion.

The difference in the criterion generally adopted in extension and the decision principle likely to be followed by farmers may be one of the reasons for a slow rate of adoption of improved technology among farmers. Studies to find out the decision criteria being followed by farmers and how those can be adjusted to meet the national goals of production, can form sound basis for extension approaches to be followed.

One may raise the question as to how to change the complex under which the farmers may be able to make their decisions on less conservative basis to achieve the desired objectives of economic development. The development of irrigation projects, control of insect pests, extension of credit facilities on easy terms, etc., and last but not the least imparting education to farmers on decision making, are the instruments which are generally helpful in this respect.

The Pessimism-Optimism index of Hurwicz can be invoked for some recommendations. The conservatism (risk aversion) of different farmers varies depending on their nature, environments, resource position, etc. It suggests that the recommendations to different farmers may be tailored to suit their psychological set up, environments, etc. The rate of adoption of improved technology could be fairly stepped up by taking this into account.

The farmers may be using the subjective probability criterion to some extent, on the bases of their own experiences and those of their neighbours. The improvements in weather forecasts and timely dissemination of such information to farmers can therefore assist them in improving their decisions.

Let us examine the pay-off matrix (yield response figures given in Appendix I) derived from the trials conducted in one region (Nilokheri) in the Punjab State. Data are available for only two years.

PAY-OFF MATRIX (NET INCOME PER ACRE)

(in Rupees)

Doses	Paddy 1954-55	Paddy 1955-56	Minimum of Row	Wheat 1954-55	Wheat 1955-56	Minimum of Row
1. 20 (lb.) N	81.4	87.4	81.4	55.0	67.8	55.0
2. 40 (lb.) N	89.6	135.2	89.6	100.4	73.2	73.2
Maximum of Column ..	89.6	135.2		100.4	73.2	

The Saddle point both for paddy and wheat exists for Wald criterion. It gives 40 (lb.) N for paddy and 40 (lb.) N for wheat. The security levels respectively are Rs. 89.6 and Rs. 73.2. The Laplace criterion determines the same acts, but the values for paddy and wheat are Rs. 112.4 and Rs. 86.8. The Savage regret criterion also confirms the selection of the act suggested by Wald and Laplace criteria.

REGRET MATRIX

Doses	Year			Year		
	1954-55	1955-56	Maximum of Row	1954-55	1955-56	Maximum of Row
1. 20 (lb.) N	8.2	47.8	47.8	45.4	5.4	45.4
2. 40 (lb.) N	0	0	0	0	0	0

The above three criteria suggest the same act, but the values obtained are quite different. These differences in the values of game suggest adjustments in approaches of extension. If the high values suggested by the Laplace criterion are given to farmers, the farmers may not be able to obtain these gains in the year. As such, they are likely to lose faith, may be partially, in these recommendations. It may happen despite the fact that of their being benefited, though to a lesser degree, by using those recommendations.

Paddy and wheat are generally grown at the same farm and to some extent are competitive for resources in the region under reference. The applications of fertilizers to paddy seems to be more remunerative in all years than in the case of wheat. The recommendation from the results emerges that paddy may be preferred over wheat in the competitive range for resources and where paddy cannot be grown due to lack of irrigation facilities, wheat may be raised.

CONCLUSIONS

The decision making criteria discussed under full ignorance and partial ignorance about the states of nature seem to be quite relevant for taking decisions at macro and farm levels, in the countries less developed in agriculture, where the returns largely depend on "vagaries" of nature (scarcity of rainfall, weather conditions susceptible to insect pests and plant diseases, etc.), rather than on its "bounties." Apart from the dominant role of nature, small sizes of farms, characterised by shortage of sufficient capital in a majority of cases, have made the owners of those farms mostly conservative and satisficers in nature. The farmers may, therefore, be following generally conservative criteria. However, the value of studies designed to find out the decision criteria being followed by different classes of farmers to form bases of extension approach need hardly be emphasized.

The recommendations to farmers by the extension service are generally based on Laplace criterion, while the receivers may be largely pursuing conservative criteria in their decisions due to their natural environments, resources position, etc. This may be one of the reasons of the slow rate of adoption of improved techniques by farmers especially of a considerable number of reversions to old techniques among farmers who earlier adopted improved practices.

The farmers differ widely in their resource position, environment and psychological set-up. The recommendations to them are generally given on a blanket cover bases, same to every one in a particular region. The Pessimism-Optimism index of Hurwicz could be profitably employed to tailor these recommendations to suit their conditions. It is likely to step up the rate of adoption of the improved technology. The improvements in weather forecasts and the timely dissemination of the information on weather to farmers will improve their decisions based on subjective probability criterion. These decisions, at present may be generally based on their own past experiences and of their neighbours. Coupled with steps to change the complex of factors which has led the farmers to conservatism, the education to farmers on decision making through the extension service may be immensely helpful in stepping up agricultural production.

These criteria could also be used at macro level decisions in certain cases. These may not become the sole bases for decisions at that level, but their consideration will help to build up expectations about future outcomes.

In the end, it may be added, that the knowledge and techniques developed so far on decision making under uncertainty are far from complete. Further researches in the field are the dire need of the present.

APPENDIX

A : Response to Fertilizer Doses (All Centres)

I. Paddy (Yield per Acre mds.)

S. No.	Doses	Year 1953-54	1954-55	1955-56
1.	20 (lb.) N ..	2.8	4.9	4.7
2.	40 (lb.) N ..	4.5	7.6	7.8
3.	20 (lb.) P ..	2.6	4.3	2.9
4.	20 (lb.) N + 20 (lb.) P ..	4.9	7.1	6.7
5.	20 (lb.) N + 40 (lb.) P ..	5.7	7.4	7.7
6.	40 (lb.) N + 20 (lb.) P ..	6.1	7.9	9.2
7.	Control ..	19.8	21.8	22.4

Price of paddy = Rs. 12 per maund.
Cost of 20 (lb.) N = Rs. 17.
Cost of 20 (lb.) P = Rs. 15.

II. Wheat (irrigated)

S. No.	Doses	Year 1953-54	1954-55	1955-56
1.	20 (lb.) N ..	2.2	3.3	3.2
2.	40 (lb.) N ..	3.5	5.9	5.1
3.	20 (lb.) P ..	1.1	1.5	1.0
4.	40 (lb.) P ..	2.5	2.6	1.8

Price of wheat = Rs. 16 per maund.
Cost of 20 (lb.) N = Rs. 17.
Cost of 20 (lb.) P = Rs. 15.

B : RESPONSE TO FERTILIZER DOSES AT ONE CENTRE (NILOKHERI, PUNJAB)

I. Paddy (Yield per Acre mds.)

S. No.	Doses	Year 1954-55	1955-56
1.	20 (lb.) N	8.2	8.7
2.	40 (lb.) N	10.3	14.1

II. Wheat (irrigated)

S. No.	Doses	Year 1954-55	1955-56
1.	20 (lb.) N	4.5	5.3
2.	40 (lb.) N	8.4	6.7